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RADC-TR- 67-177

VARIABLE POLARIZER

L. J. Lavedan Jr.
Sperry Microwave Electronics Company

TECHNICAL REPORT NO. RADC-TR-67-177
May 1967

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Rome Air Development Center
Research and Technology Division
Air Force Systems Command
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VARIABLE POLARIZER

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Sperry Microwave Electronics Company

AFLC, GAFB, N.Y., 8 Jun 67-148

FOREWORD

This Semiannual Report covers the work performed on Contract F30602-67-C0004 and covers the period July 1966 to February 1967. The submission date is March 1967. Work was conducted under Project 4506, Task 450601.

The work on this contract is being performed by the Sperry Microwave Electronics Company, Division of Sperry Rand Corporation, Clearwater, Florida. It is under the direction of Mr. Patrick Romanelli, (EMATE) of Rome Air Development Center, Griffiss Air Force Base, Rome, New York.

The secondary report number applied by Sperry to this report is SJM-220-4320-1.

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This report has been reviewed and is approved.

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ABSTRACT

The objective of this work is the study and experimental verification leading to the design of a high power S band variable polarizer. This polarizer is to transform the TE_{10} mode to vertical linear, clockwise circular, counterclockwise circular, and horizontal linear polarizations. Switching time between degrees of polarization is to be 200 microseconds or less. The characteristics of the variable polarizer include the objectives of 1 mw peak, 2 kw average power operating over the band, 3.1 MHz to 3.6 MHz with the study including the feasibility to increase power handling to 10 mw peak, 20 kw average.

Recent results indicate the feasibility of attaining the design goals by the use of nonreciprocal waveguide latching phasers as the active elements of the polarizer. Polarizer power levels to 920 kw peak and 3600 watts average (depending upon polarizer configuration) have been attained, the present limit being the testing facilities available.

Studies have included various polarizer configurations which appear compatible with system concepts and the development in individual phaser elements necessary to meet polarizer requirements.

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INTRODUCTION

Program Objectives. The purpose of this program is to study the feasibility of producing a very high power, S band polarizer capable of fast switching to any one of several modes of operation. The work on this program can be divided into two general tasks*:

- The study of the polarizer elements in their relationship to the overall unit in its system environment.

- The study and development of specific components as applied to the overall polarizer.

The end result of these tasks will be the development of techniques and the accumulation of test data which will lead to a recommended polarizer design capable of operation at extreme peak and average power.

The development phase of the program includes a design study and experimental evaluation of breadboard hardware operating to an intermediate power level. Performance goals for this phase of the program are as follows:

1. Power	1 Mw peak, 2 kw average (10 Mw peak, 20 kw average - final goal)
2. Bandwidth	500 MHz min
3. Center frequency	3.35 GHz
4. VSWR	1.2 max
5. Insertion loss	1 db max
6. Switching time	200 usec max
7. Pulse width	40 usec min
8. Repetition rate	[illegible]0 pps
9. Isolation between polarization channels	30 db min

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* Each of these tasks is considered in this First Semiannual Report in light of present and predicted technology.

10.	Phase nonlinearity at each polarization	Not greater than ±2.5° combined periodic peak and random rms
11.	Phase nonlinearity excluding that due to waveguide	5° max, frequency 3.15 to 3.55 GHz 15° max, frequency 3.10 to 3.60 GHz
12.	Amplitude response	0.5 db combined periodic peak and random rms, max
13.	Differential phase and amplitude between polarization channels	Phase 0.5° max Amplitude 0.2 db max
14.	Drift	Phase 1° per hour max Amplitude 0.2 db per hour max
15.	Environmental	
	Operating	-22°C to +49°C
	Nonoperating	-40°C to +49°C

SECTION II

POLARIZER CONSIDERATIONS IN RELATION TO SYSTEM ENVIRONMENT

2.1 BASIC POLARIZER

The polarizer described herein is a waveguide device which converts an incoming signal from the power source in the fundamental TE_{10} mode to two orthogonal components with definite but variable time phase relationships in a single output structure. Similarly, any return signals entering the output port will be suitably converted into one or more receive signals for further receiver processing.

Depending upon the type of phasing elements employed and the complexity of the polarizer system, this return signal will appear at the input or transmit port or one or more specifically designated receive ports. If one or more separate receive ports are employed, the polarizer will function as a duplexer in that isolation of the transmitter from the receiver is attained. This isolation can exceed 20 db.

A simplified polarizer configuration is shown in Figure 1.

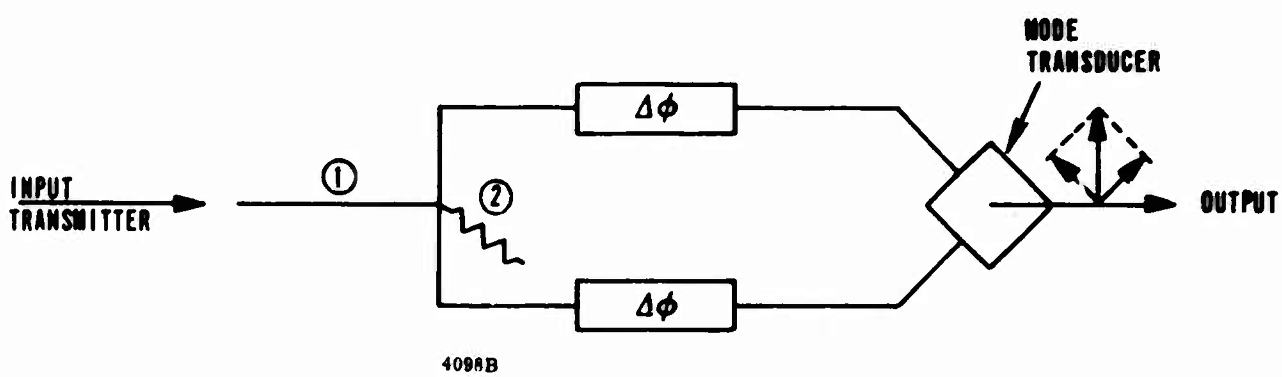

Figure 1. Simplified Polarizer Configuration

A single incoming signal is divided into two equal parts by means of a "Magic-T" or "short slot hybrid." The two outputs have a specific relative phase. These two signals pass through suitable phasers which alter the relative phase difference between the signals to predetermined values. These two signals are then fed to a suitable multimode transducer. The resultant output is a signal that can be described as being polarized elliptically to any degree from circular to linear and the axis of the elipse is variable from a reference plane of the multimode transducer.

The mode transducer shown in Figure 1, although similar to those used in many existing polarizer units, is employed in a restricted manner in that under all modes of operation including linear polarization, two signals (ideally of equal magnitude) enter the device. This restriction can be seen from the relative field description of Figure 2.

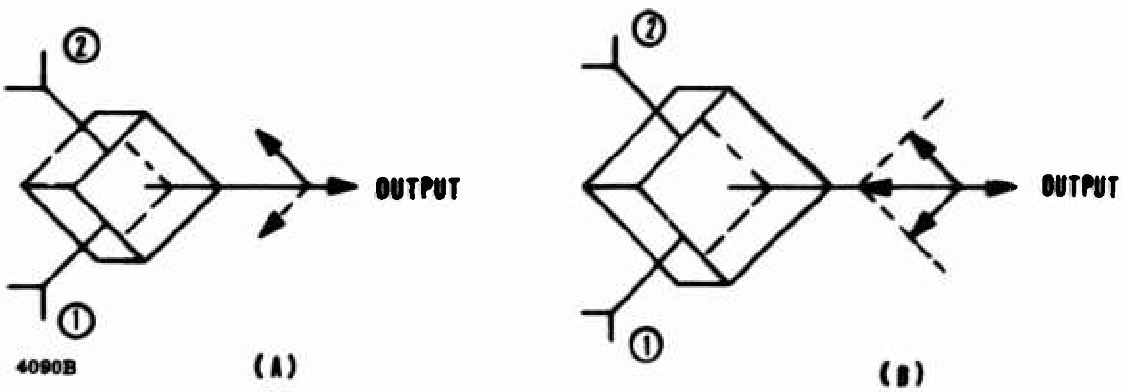

Figure 2. Relative Field Patterns

If a signal is fed into port 2 of Figure 2A, then it can be designated as the solid arrow at the output. Similarly, a signal in port 1 can be designated by the dashed arrow at the output. A signal at either input will produce a linearly polarized output (the angle of the polarization varies). However, as in Figure 2B, if two signals are inserted into the structure at ports 1 and 2 with relative time phase so as to produce two orthogonal outputs with equal time phase, the resultant output can be described also as a linear wave which is offset from those of Figure 2A by 45° in space. This offset can be corrected if necessary by proper rotation of the feed structure.

The mode of operation of Figure 2B is imposed on all polarizer configurations described herein because it allows a balanced operation of the phaser elements with respect to operating power and, therefore, also with respect to the resultant operating temperature. This balanced condition should reduce the problem generated by the temperature time constants inherent in the phaser materials.

2.2 SPECIFIC POLARIZER CONFIGURATIONS

It is necessary to impose restrictions on the elements of the polarizer at this point, especially the phaser elements, so that further analysis of possible polarizer configurations can be accomplished.

For purposes of analysis, each phaser element used will be:

1. Nonreciprocal,
2. Capable of 90 degrees phase delay,
3. Of the latching (remanent) variety.

These restrictions are essentially in agreement with what appears feasible for present and near future phaser development in accordance with the specifications of this program.

2.2.1 Single Receiver Port Polarizer

The simple polarizer configuration of Figure 1 can be expanded into the configuration of Figure 3.

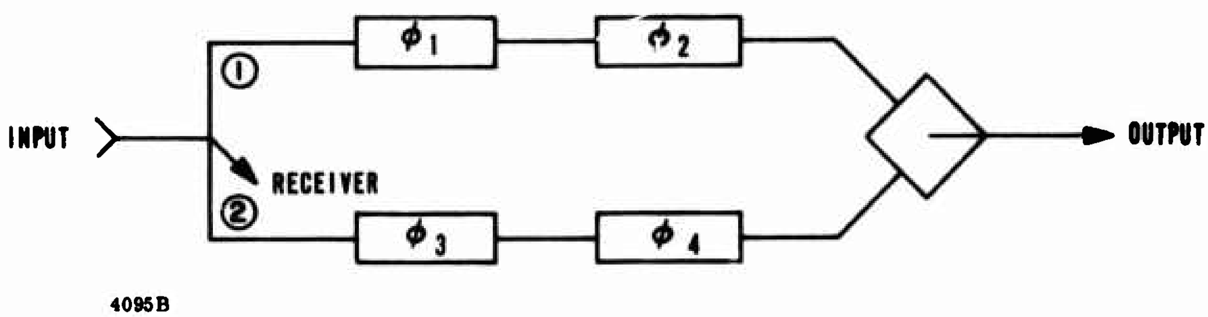

Figure 3. Single Receiver Port Polarizer

Four phaser elements are used in this device. Each element can be switched independently from the remainder. The input power splitter is of the "Magic-T" variety giving zero phase difference between arms 1 and 2. For simplicity let us consider a single setting for ϕ_1, ϕ_2, ϕ_3, and ϕ_4 that is:

$$\left.\begin{array}{l}\phi_1 = 0\\ \phi_2 = -90\\ \phi_3 = 0\\ \phi_4 = 0\end{array}\right\} \quad \text{Forward Direction (input to output)}$$

The signals appearing at the ports of the mode transducer will have a 90 degree phase difference producing a circular polarization (assuming equal amplitudes).

Receive signals returning through the mode transducer will have the same phase relationship as on transmit. Because the phase elements are nonreciprocal, however, return element phase will be (if elements are not switched):

$$\phi_1 = -90$$
$$\phi_2 = 0$$
$$\phi_3 = -90$$
$$\phi_4 = -90$$

The return signal will then recombine into a single signal which travels to the input port. Under such conditions no duplexing isolation is attained in the polarizer and a separate duplexer for separation of the receive signals is required. If, however, ϕ_3 and ϕ_4 are reversed to produce $\phi_3 = \phi_4 = 0$ for the return signals, then the receive signal will progress toward the receive port as designated in Figure 3. Switching between receive and transmit is fully compatible for the polarizer specification and will be considered in all configurations covered in this report.

2.2.2 Calculations on Design of Single Receiver Port Polarizer

Insertion loss and differential insertion phase for the polarizer of Section 2.2.1 were calculated based upon realistic estimates of likely deviations from nominal of the various components of the polarizer. All calculations were based upon the deviation obtained when the polarizer is in the receive condition for circular polarization.

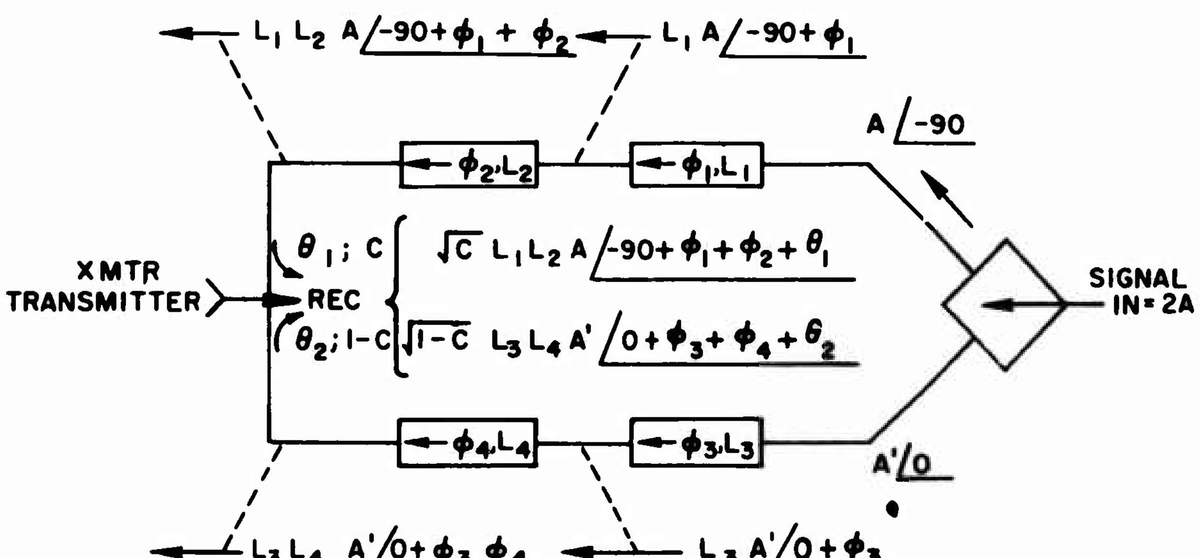

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Figure 4. Signal Relationships in Single Receiver Port Polarizer

Understanding the terms of the expressions used in Figure 4 will be helpful.

A and A' are the two orthogonal signals as derived in the multimode transducer from a signal of power level 2A. The angles indicated in Figure 4 are -90 and 0 degrees; these are values for the ideal transducer which will be altered in one set of calculations to indicate a non-ideal transducer.

The L terms of Figure 4 are the differential voltage losses associated with the phaser elements. This loss is not the insertion loss of the various elements but is included to indicate a change in loss through the phasers depending upon their phase position.

The ϕ terms are the values of differential phase shift encountered through the various phaser elements on the particular mode of operation under study.

The θ terms include the phase shift through the input "Magic-T" and in the calculations, include any variations with frequency.

C is the power coupling coefficient of the "Magic-T".

It can be seen from Figure 4 that the resultant receiver port signal is the resultant of two signals. That is:

$$S_1 = \sqrt{C}\, L_1 L_2 A \,\underline{/-90 + \phi_1 + \phi_2 + \theta_1}$$

$$S_2 = \sqrt{1-C}\, L_3 L_4 A' \,\underline{/0 + \phi_3 + \phi_4 + \theta_2}$$

The magnitude of the resultant signal is given by

$$|S| = \sqrt{X_1^{\,2} + X_2^{\,2} + 2X_1 X_2 (\cos \delta_1 - \delta_2)}$$

where

$$X_1 = \sqrt{C}\, L_1\, L_2\, A$$

$$X_2 = \sqrt{1-C}\, L_3\, L_4\, A'$$

$$\delta_1 = -90 + \phi_1 + \phi_2 + \theta_1$$

$$\delta_2 = 0 + \phi_3 + \phi_4 + \theta_2$$

The angle of the resultant signal is

$$\bar{\theta} = \tan^{-1} \left[\frac{X_1 \sin \delta_1 + X_2 \sin \delta_2}{X_1 \cos \delta_1 + X_2 \cos \delta_2} \right]$$

The ratio of $\frac{|S|^2}{2A}$ is the loss associated with the polarizer as a result of variations in the L, C, ϕ, θ terms. This does not include the insertion loss of the various components.

$\bar{\theta}$ is the angle of the output signal as referenced to the angle of the two signals A and A'. $\bar{\theta}$ does not include the insertion phase of the unit which must be determined by line lengths, etc. but which is fixed and is a function of the waveguide parameters only.

Table I is a summary of cases studied under the conditions of Figure 4. Each case was studied at five points across the operating band with the various parameters varying in a manner as typically expected with frequency. Cases 1 through 5 assume no deviation from ideal for the multimode transducer whereas cases 6 and 7 include variations in amplitude and phase respectively. The addition of errors in mode transducer characteristics, however, yields results similar to further perturbations of cases 1 through 5.

Figures 5 through 11 depict the results of Table I in graphic form with each curve representing one of the cases of Table I.

Table I. Characteristics of Single Receiver Port Polarizer for 7 Cases

	CASE 1					CASE 2				
	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$
θ_2	170	178	180	182	190	170	177	180	183	190
L_2	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772
C	.4786	.4786	.5012	.5248	.5248	.4786	.4786	.5012	.5248	.5248
ϕ_2	-85	-87.5	-90	-92.5	-95	-85	-87.5	-90	-92.5	-95
$\frac{\lvert S\rvert^2}{2A}$	.9231	.9382	.9828	.9744	.9593	.9231	.9375	.9828	.9737	.9593
$\bar{\theta}$	-13.3'	+1.0'	0	-1.65'	+14.3'	-13.3'	-2.0'	0	+1.3'	+14.3'

	CASE 3					CASE 4				
	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$
θ_2	170	178	180	182	190	170	178	180	182	190
L_2	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772
C	.4876	.4876	.5012	.5248	.5248	.4876	.4876	.5012	.5248	.5248
ϕ_2	-86	-88.25	-90	-92.75	-95	-86	-88	-90	-92	-94
$\frac{\lvert S\rvert^2}{2A}$	.9252	.9387	.9828	.9742	.9593	.9252	.9387	.9828	.9747	.9614
$\bar{\theta}$	-16.3'	-1.6'	+1.0'	-2.3'	+14.3'	-16.3'	-0.5'	0	-0.15'	+17.3'

Table I. Characteristics of Single Receiver Port Polarizer for 7 Cases (Continued)

	CASE 5					CASE 6*				
	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$
θ_2	170	178	180	182	190	170	178	180	182	190
L_2	.9722	.9722	.9722	.9722	.9722	.9722	.9722	.9722	.9722	.9722
C	.5248	.5248	.5012	.4786	.4786	.4786	.4786	.5012	.5248	.5248
ϕ_2	-86	-88	-90	-92	-94	-85	-87.5	-90	-92.5	-95
$\frac{\|S\|^2}{2A}$	.9614	.9747	.9828	.9387	.9252	.9380	.9365	.9548	.9523	.9376
$\bar{\theta}$	-17.3'	+0.15'	0	+0.5'	+16.3'	-13.1'	-1.2'	0	-2.0'	+13.6'

	CASE 7**				
	$f_o-2\Delta$	$f_o-\Delta$	f_o	$f_o+\Delta$	$f_o+2\Delta$
θ_2	168	176	178	180	188
L_2	.9722	.9722	.9722	.9722	.9722
C	.4786	.4786	.5012	.5248	.5248
ϕ_2	-85	-87.5	-90	-92.5	-95
$\frac{\|S\|^2}{2A}$	.9184	.9367	.9825	.9754	.9634
$\bar{\theta}$	23'	5.5'	6'	7.6'	8.3'

NOTES: $L_1 = L_3 = L_4 = 1$
$\phi_1 = \phi_3 = \phi_4 = 0$
$\theta_1 = 0$
$A = A' = 1$
4Δ = Operating Bandwidth

* A = 1, A' = .9772 (0.2 db)
** Angle of A out of Multimode Transducer = -88 degrees

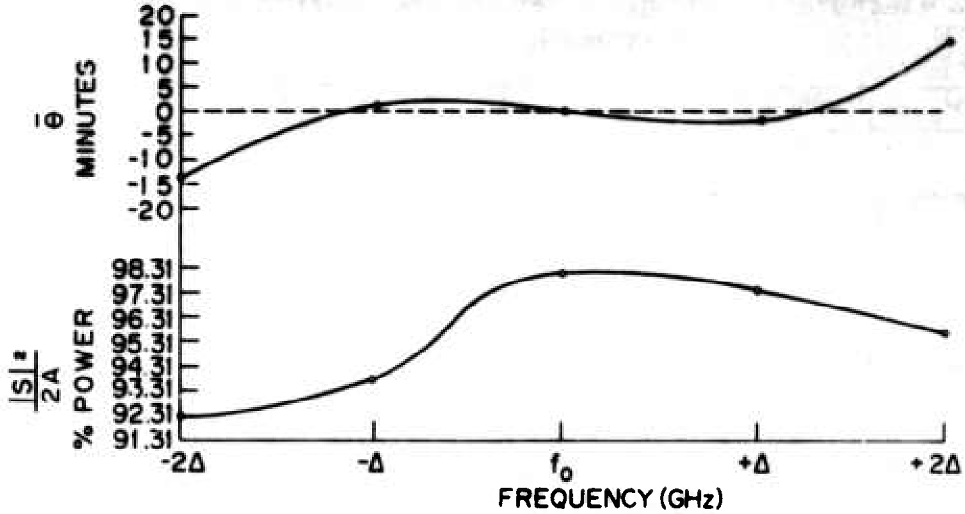


Figure 5. Single Receiver Polarizer - Case 1

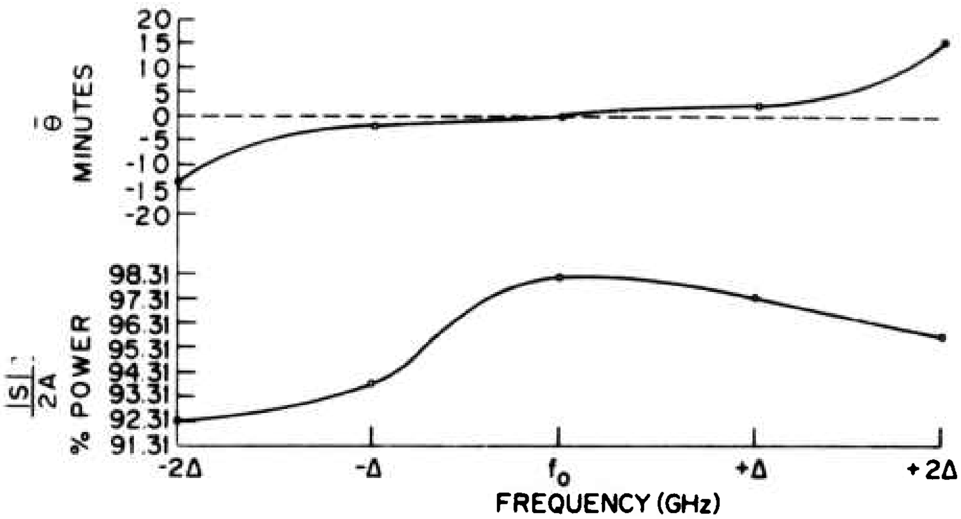


Figure 6. Single Receiver Polarizer - Case 2

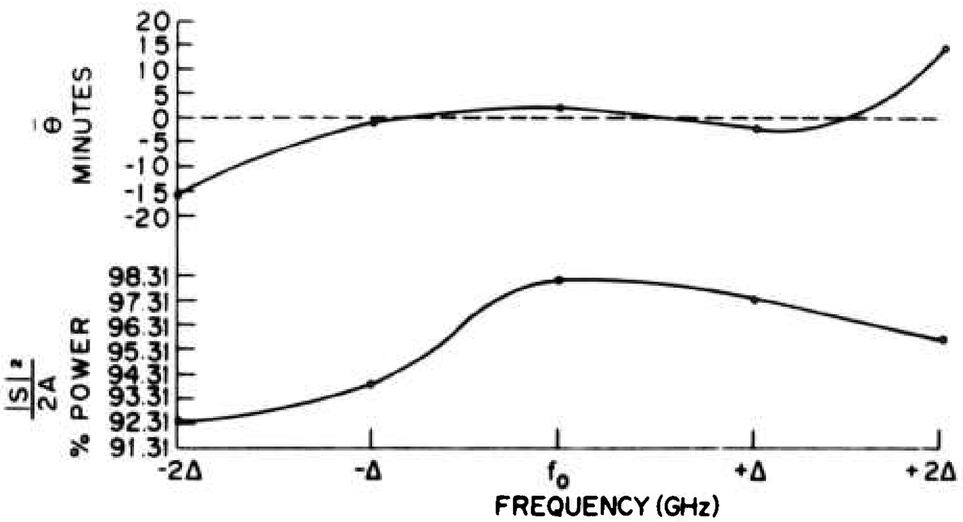


Figure 7. Single Receiver Polarizer - Case 3

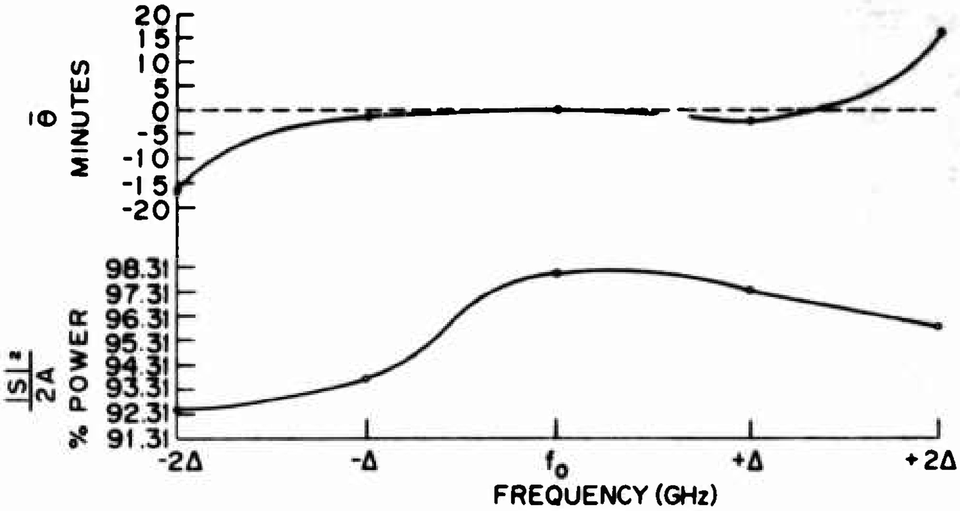


Figure 8. Single Receiver Polarizer - Case 4

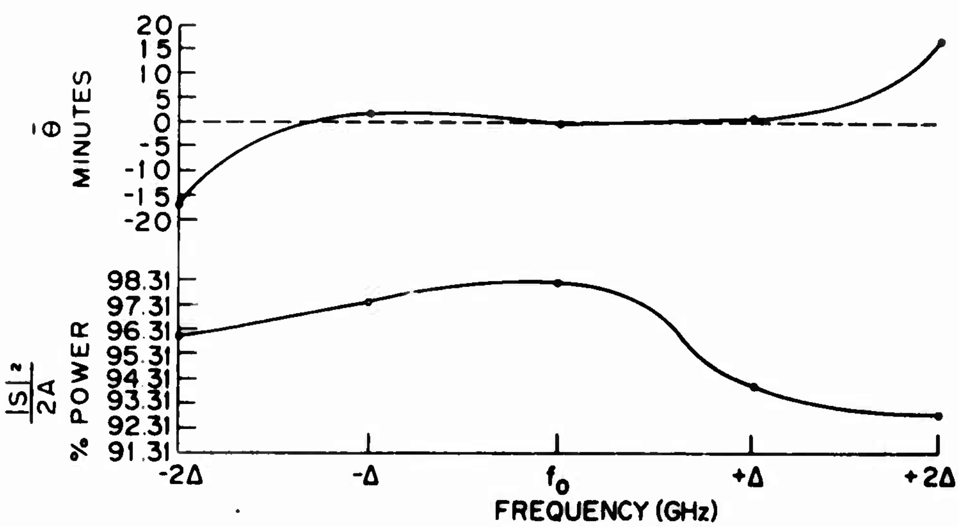


Figure 9. Single Receiver Polarizer - Case 5

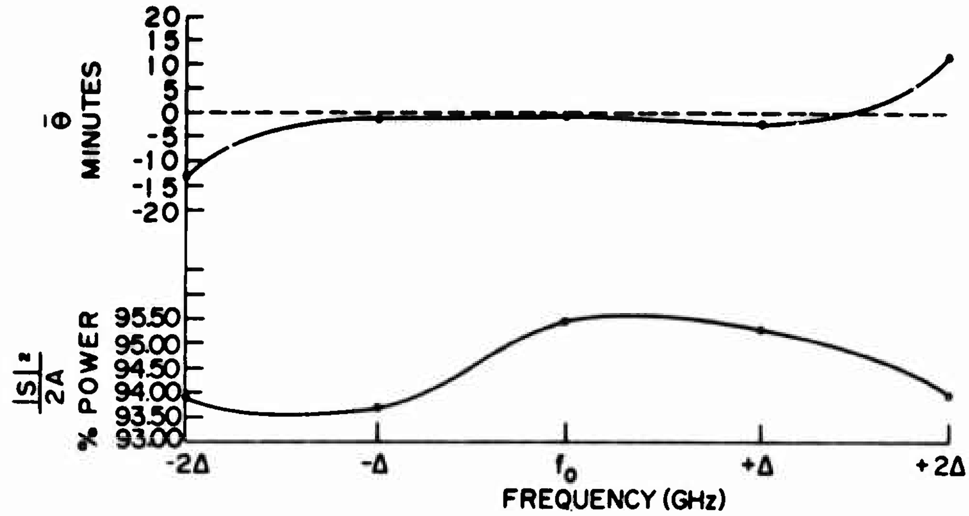


Figure 10. Single Receiver Polarizer - Case 6

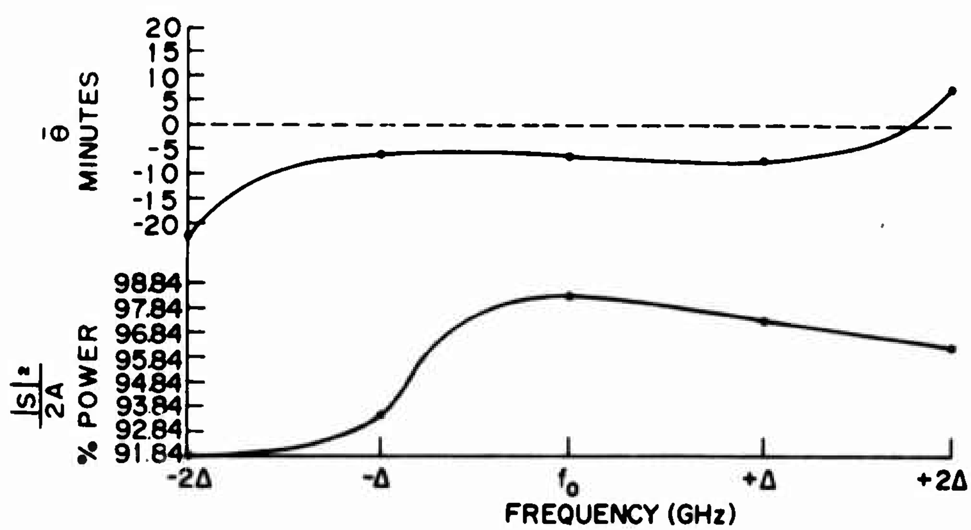


Figure 11. Single Receiver Polarizer - Case 7

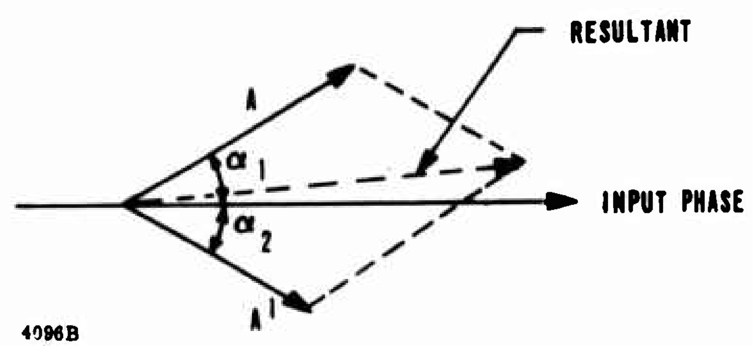
__Interpretation of Data.__ It can be seen from the data of Table I and the corresponding illustrations that the input-to-output phase deviation is quite small for all cases chosen. This has been accomplished by partially matching the deviations in phase of the input coupler with those of the phase shifter.

It should be noted that all amplitude terms also follow a similar pattern with frequency except case 5 where the variation with frequency of the input coupler was reversed.

It should also be noted that the input coupler characteristics have been chosen to be X $\pm 10^{\circ}$ and 3 ± 0.5 db over the operating band. These characteristics are greater than those actually anticipated but were chosen to determine trends in the polarizer performance.

Maximum deviation in amplitude occurred for case 7 which assumes a 2 degree error in the multimode coupler; an error which can, in practice, be corrected by proper adjustment of the insertion phase of the phase shift elements. This deviation was approximately 0.3 db over the operating band. If, however, the slope of the coupler is opposite that of the phase shift element, errors can become quite large.

Using the simplified sketch below, one may qualitatively study the system.



The vectors A and A' represent the two signals out of the receive port which produce the resultant receive signal. As long as A and A' are balanced about the input phase in complementary quadrants, the resultant phase error will be quite small.

If the resultant angles of these signals are large, however, there will be a noticeable reduction in amplitude. Likewise, a large difference in amplitude of the two signals, although of equal angle ($\delta_1 = \delta_2$) will result in a phase error. In order to assure optimum performance, it is necessary to reduce changes in the angles δ_1 and δ_2 to a minimum or to compensate for these deviations by appropriate deviations in amplitude.

In practice, any deviations from nominal in the coupler at center frequency will be eliminated by properly compensating the insertion phase of the phase shift elements. It is possible to partially compensate for loss unbalance by adjusting the differential phase to other than 90 degrees at center frequency. Because of the complexity of the calculations, it appears to be more feasible to study these various methods of compensation on the experimental hardware to be completed at a later date as part of this program. Further studies, however, will be made for the more practical cases where the phase slope of the phase shift elements is essentially zero and the slope of the coupler is confined to a smaller deviation.

2.2.3 System Considerations

The single receiver port polarizer configuration of Section 2.2.1 possesses one large system difficulty. If a polarization other than that intended is received (which will normally occur from practical targets) because of the single receive port of this polarizer, it cannot be separated from the principal target return and will appear as an error in the system. In addition, if it is desirable to observe principally one of these minor return polarizations using a single receiver output system (which is attained by proper switching of the phaser elements), these weak return signals (as compared to the principal/transmit polarization return signal) will be completely masked out. It is therefore possible to receive only the principal or transmitted polarization on receive.

Such a configuration greatly limits the usefulness of a tracking system where data from the minor return polarizations will indicate parameters such as shape, roll, and tumble of a target.

2.2.4 Dual-Channel Receiver System

The dual-channel receiver polarizer system is similar to the single-channel receiver system except by providing two receiver outputs, phase and amplitude information of two orthogonal receive components is retained from antenna to receiver. Thus, if a suitable phase and amplitude IF system is employed in conjunction with a suitable reference signal, electronic circuitry can separate the various polarizations present in a return signal for any transmit polarization.

The polarizer configuration is given in Figure 12. Again, the phaser elements ϕ_1 through ϕ_8 are 90 degree nonreciprocal elements and are switched between transmit and receive.

The polarizations attainable are given in Table II along with the positions of the phase shifters (viewed in transmit direction) for each mode. It should be noted that several phaser combinations will produce the same polarization; there appears no advantage to any particular choice.

Table II. Phase Shift of Each Element for Various Polarizations

Polarization	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	ϕ_6	ϕ_7	ϕ_8
	TRANSMIT CONDITION							
	PHASER POSITION							
→	0	0	0	0	0	0	0	0
←	-90	-90	-90	-90	-90	-90	-90	-90
↑	-90	-90	-90	-90	0	0	0	0
↓	0	0	0	0	-90	-90	-90	-90
↻	0	-90	0	-90	0	0	0	0
	-90	0	-90	0	0	0	0	0
	-90	-90	-90	-90	-90	0	-90	0
	-90	-90	-90	-90	0	-90	0	-90
↺	0	0	0	0	-90	0	-90	0
	0	0	0	0	0	-90	0	-90
	0	-90	0	-90	-90	-90	-90	-90
	-90	0	-90	0	-90	-90	-90	-90
	RECEIVE CONDITION							
Any Polarization	-90	-90	0	0	0	0	-90	-90
	0	0	-90	-90	0	0	-90	-90
	-90	-90	0	0	-90	-90	0	0
	0	0	-90	-90	-90	-90	0	0

It is interesting to note that only one receive condition is required for all transmit polarizations.

This polarizer system likewise functions as a duplexer and will probably be capable of 20 db isolation between transmitter and receiver.

If, however, phase matched duplexers are employed, they can be located at points A and B of Figure 12. The use of a receive mode of operation and any errors through the polarizer (on receive) are thus eliminated.

Again, when this configuration is used as a duplexer/polarizer or when used with separate duplexers, it has the advantage over more conventional designs as all phaser and duplexer elements (if used) are subjected to equal powers and thus the system experiences a power/temperature differential minimum.

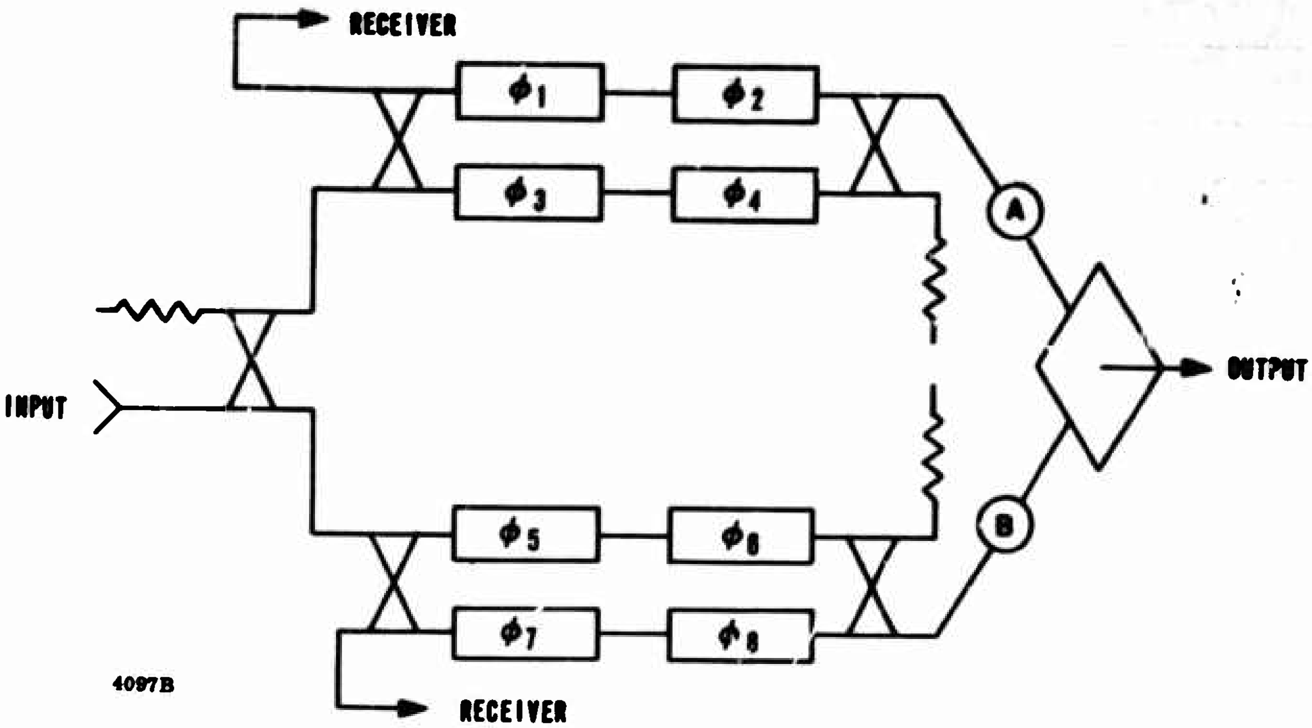


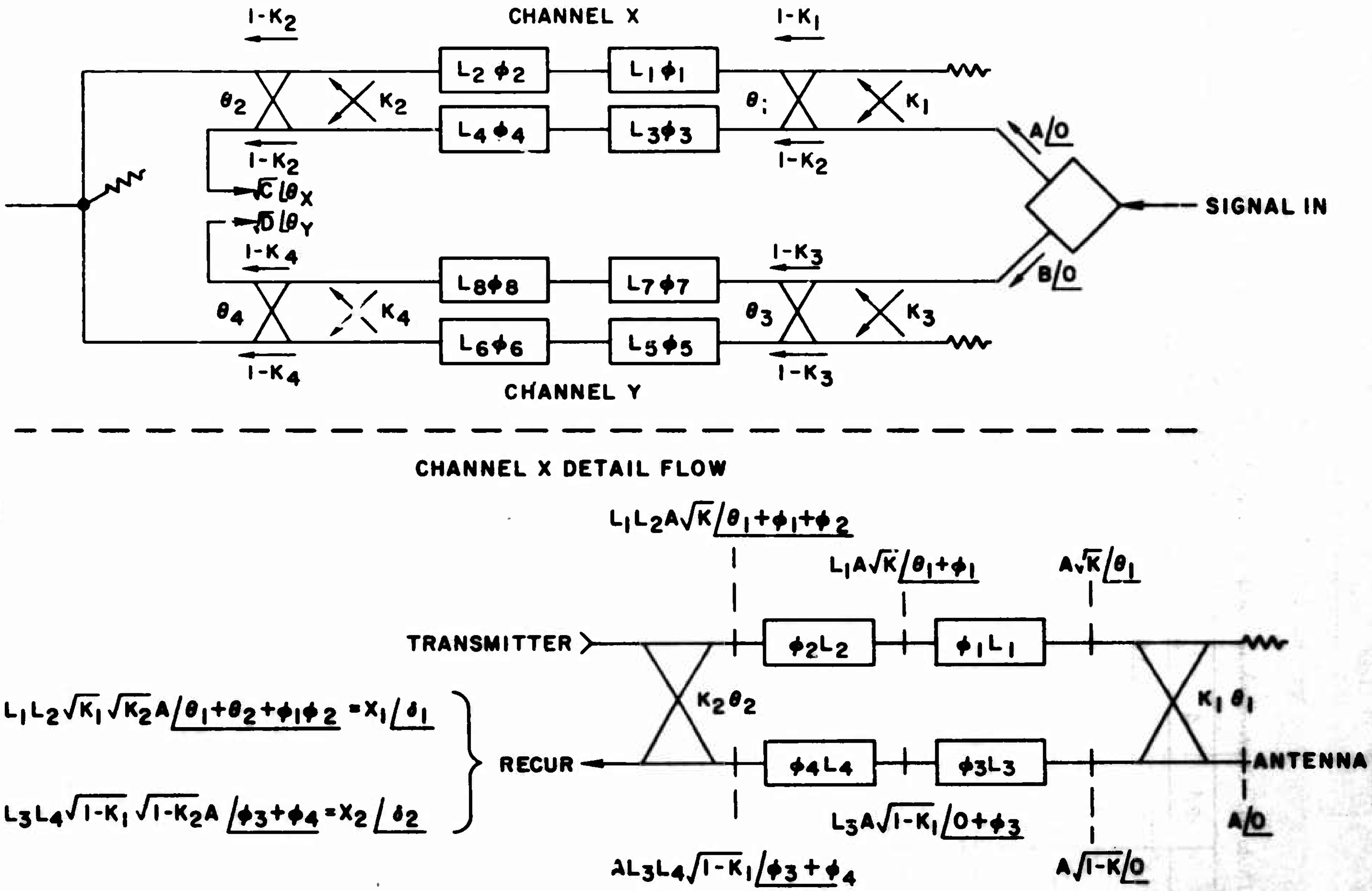
Figure 12. Dual-Channel Receiver Polarizer

2.2.5 Calculations on the Design of Dual-Channel Receiver Polarizer

A study of the output signals relative to the input reference signal and relative to each other has been carried out. Figure 13 indicates the relative power level and phase angle as the energy flows through the polarizer. As before, the terms C, D, θ_x, and θ_y are summations of signals appearing at the outputs from multiple signal paths. The polarizer is switched to the receive case as outlined in Table II. Table III is a summary of seven cases involving variations in C, θ, and ϕ, these being variable also with frequency. Cases 1 through 5 of Table III consider the mode transducer as an ideal element. Case 6 assumes an unbalance in power output and case 7 assumes an improper phase output from the multimode transducer.

Again, the insertion loss described by the L terms implies differential loss only, and the insertion phase of the polarizer has been neglected.

Because of its two outputs, this dual receiver polarizer will involve not only phase and amplitude relationships to the input but also the relationships between the two outputs assuming some specific input relationship. Figures 14 through 27 describe in graphic form these relationships given in Table III.



$$C = X_1^2 + X_2^2 + 2X_1X_2(\cos[\delta_1 - \delta_2]);\ \theta_X = \tan^{-1}\left[\frac{X_1 \sin\delta_1 + X_2 \sin\delta_2}{X_1 \cos\delta_1 + X_2 \cos\delta_2}\right]$$

4072B

Figure 13. Dual Receiver Polarizer with Signal Flow

Table III. Characteristics of Dual-Channel Receiver Polarizer for 7 Cases

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
			CASE 1					CASE 2		
$\theta_3 = \theta_4 =$ $\theta_1 = \theta_2$	85	89	90	91	95	85	88.5	90	91.5	95
$\phi_1 = \phi_2 =$ $\phi_5 = \phi_6$	0	0	0	0	0	0	0	0	0	0
$\phi_3 = \phi_4 =$ $\phi_7 = \phi_8$	-85	-87.5	-90	-92.5	-95	-85	-87.5	-90	-92.5	-95
$K_1 = K_2 = K_3 =$	3.2db	3.2db	3.0db	2.8db	2.8db					
K_4	.4786	.4786	.5012	.5248	.5248	.4786	.4786	.5012	.5248	.5248
$L_3 = L_4 =$ $L_5 = L_6$	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772
$L_1 = L_2 =$ $L_7 = L_8$	1	1	1	1	1	1	1	1	1	1
C	.9244	.9498	.9524	.9538	.9286	.9244	.9485	.9524	.9527	.9286
D	.9282	.9534	.9544	.9495	.9243	.9282	.9523	.9544	.9484	.9243
C - D	-.0038	-.0038	-.0020	+.0043	+.0043	-.0038	-.0038	-.0020	+.0043	+.0043
θ_x	180^o 12.5'	181^o 34.4'	180^o	181^o 14.5'	180^o 46'	180^o 12.5'	181^o 4.6'	180^o	180^o 42.5'	180^o 46'
θ_y	180^o 40'	181^o 43.7'	180^o	181^o 24.3'	180^o 16'	180^o 40'	181^o 15.8'	180^o	180^o 53.7'	180^o 16'
$\theta_x - \theta_y$	-27.5'	-9.3'	0	-9.8'	+30'	-27.5'	-11.2'	0	-11.2'	+30'

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
			CASE 3					CASE 4		
$\theta_3 = \theta_4 =$ $\theta_1 = \theta_2$	85	89	90	91	95	85	89	90	91	95
$\phi_1 = \phi_2 =$ $\phi_5 = \phi_6$	0	0	0	0	0	0	0	0	0	0
$\phi_3 = \phi_4 =$ $\phi_7 = \phi_8$	-86	-88.25	-90.5	-92.75	-95	-86	-88	-90	-92	-94

Table III. Characteristics of Dual-Channel Receiver Polarizer for 7 Cases (Continued)

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
			CASE 3 (Continued)					CASE 4 (Continued)		
$K_1=K_2=K_3=K_4$	.4786	.4786	.5012	.5248	.5248	.4876	.4876	.5012	.5248	.5248
$L_3=L_4=L_5=L_6$	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772
$L_1=L_2=L_7=L_8$	1	1	1	1	1	1	1	1	1	1
C	.9298	.9510	.9523	.9533	.9286	.9298	.9505	.9524	.9547	.9340
D	.9336	.9548	.9543	.9490	.9243	.9336	.9548	.9544	.9504	.9297
C - D	-.0038	-.0038	-.0020	+.0043	+.0043	-.0038	-.0038	-.0020	+.0043	+.0043
θ_x	180° 49.3'	180° 48.2'	180° 29'	181° 28.9'	180° 46'	180° 49.3'	181° 3.5'	180°	180° 47'	181° 39.5'
θ_y	180° 24.1'	180° 56'	180° 30.7'	181° 39'	180° 16'	180° 24.1'	181° 11.9'	180°	180° 55.1'	181° 14.3'
$\theta_x - \theta_y$	+25.2'	-7.8'	-0.7'	-10.1'	+30'	25.2'	-8.4'	0	-8.1'	+25.2'

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
			CASE 5					CASE 6*		
$\theta_3=\theta_4=\theta_1=\theta_2$	85	89	90	91	95	85	89	90	91	95
$\phi_1=\phi_2=\phi_5=\phi_6$	0	0	0	0	0	0	0	0	0	0
$\phi_3=\phi_4=\phi_7=\phi_8$	-86	-88	-90	-92	-94	-85	-87.5	-90	-92.5	-95
$K_1=K_2=K_3=K_4$	2.8db .5248	2.8db .5248	3.0db .5012	3.2db .4786	3.2db .4786	.4786	.4786	.5012	.5248	.5248
$L_3=L_4=L_5=L_6$	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772	.9772
$L_1=L_2=L_7=L_8$	1	1	1	1	1	1	1	1	1	1

Table III. Characteristics of Dual-Channel Receiver Polarizer for 7 Cases (Continued)

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
	CASE 5 (Continued)					CASE 6* (Continued)				
C	.9340	.9547	.9524	.9505	.9298	.8820	.9090	.9100	.9110	.8865
D	.9297	.9504	.9544	.9543	.9336	.9485	.9743	.9544	.9495	.9243
C - D	+.0043	-.0043	-.0020	-.0038	-.0038	-.0665	-.0653	-.0444	-.0385	-.0378
θ_x	181° 39.5'	180° 47'	180°	181° 3.5'	180° 49'	180° 12.5'	181° 34.4'	180°	181° 14.0'	180° 46'
θ_y	181° 14.4'	180° 55.2'	-180°	181° 11.9'	180° -24.1'	180° 40'	181° 43.7'	180°	181° 24.5'	180° 16'
$\theta_x - \theta_y$	+25.1'	-8.2'	0	-8.4'	+25.2'	-27.5'	-9.3'	0	-9.8'	+30'

	-2Δ	$-\Delta$	f_o	$+\Delta$	$+2\Delta$
	CASE 7**				
$\theta_3 = \theta_4 = \theta_1 = \theta_2$	85	89	90	91	95
$\phi_1 = \phi_2 = \phi_5 = \phi_6$	0	0	0	0	0
$\phi_3 = \phi_4 = \phi_7 = \phi_8$	-85	-87.5	-90	-92.5	-95
$K_1 = K_2 = K_3 = K_4$	.4786	.4786	.5012	.5248	.5248
$L_3 = L_4 = L_5 = L_6$	.9772	.9772	.9772	.9772	.9772
$L_1 = L_2 = L_7 = L_8$	1	1	1	1	1
C	.9244	.9498	.9524	.9538	.9286
D	.9282	.9534	.9544	.9495	.9243
C - D	-.0038	-.0038	-.0020	+.0043	+.0043
θ_x	180° 12.5'	181° 34.4'	180°	181° 14.5'	180° 46'
θ_y	182° 40'	183° 43.8'	180° 25'	180° 33.6'	182° 16'
$\theta_x - \theta_y$	-2° 27.5'	-2° 9.4'	-25'	+40.8'	-1° 36'

*A = .9772 (0.2 db); B = 1
4Δ = Operating Bandwidth

** δ = 2 degrees (Error out of multimode transducer from B output)

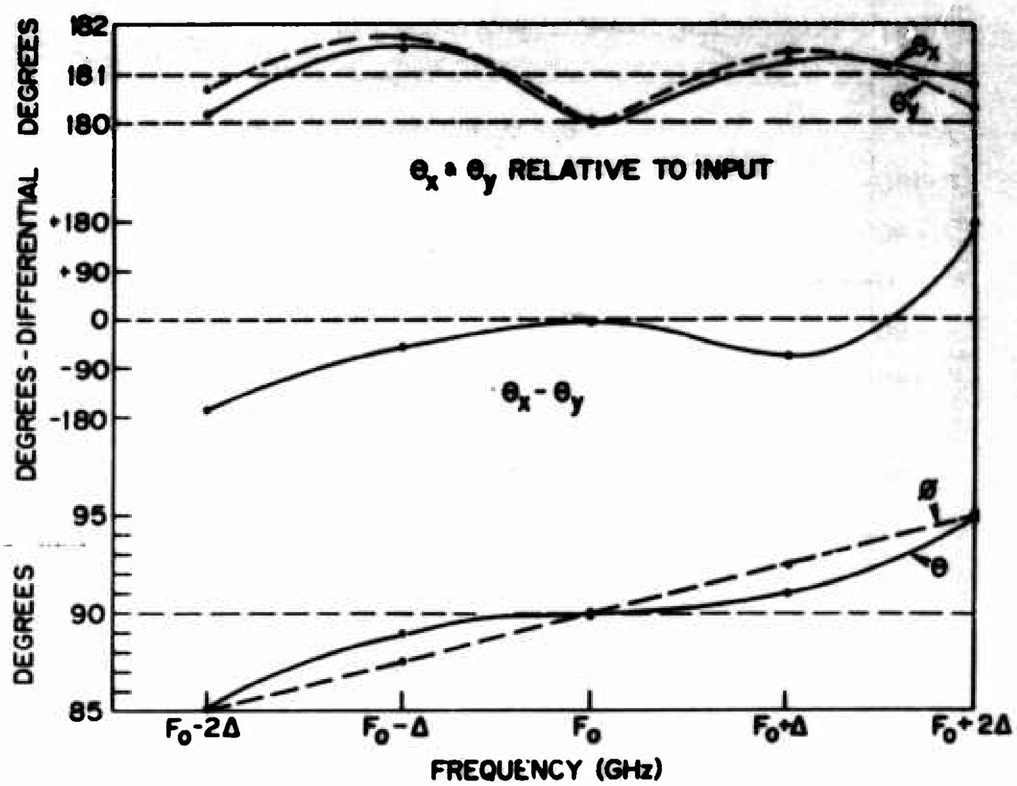


Figure 14. Dual Receiver Polarizer - Case 1

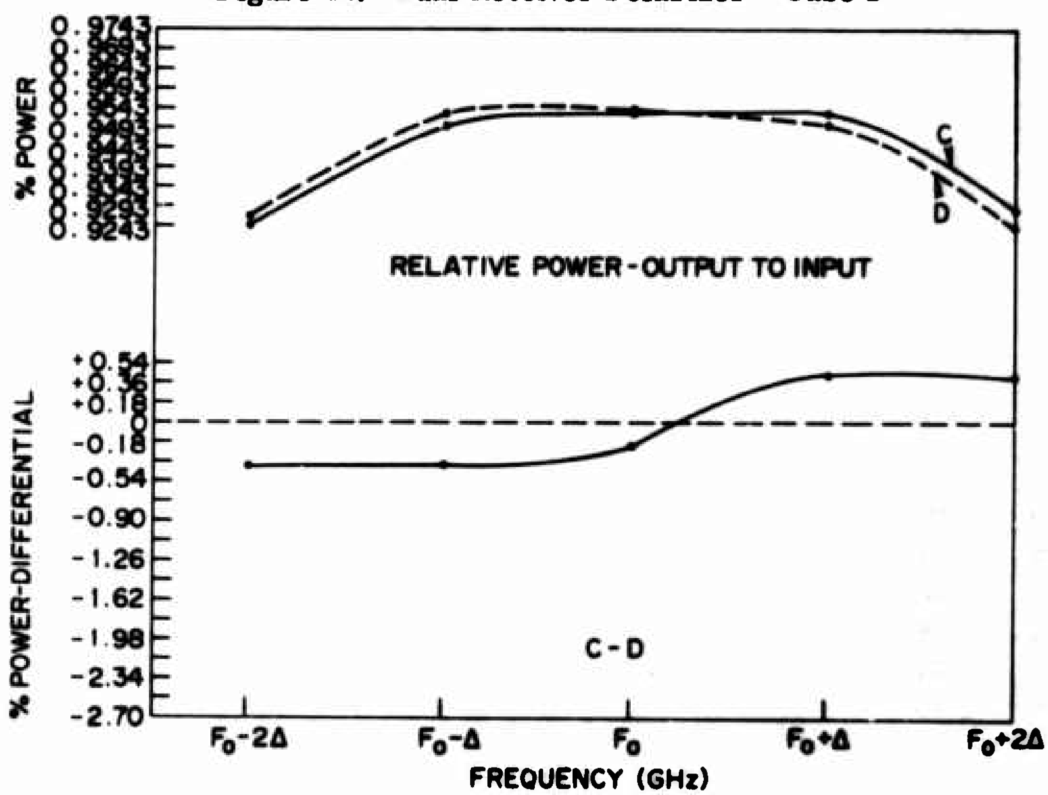


Figure 15. Dual Receiver Polarizer - Case 1

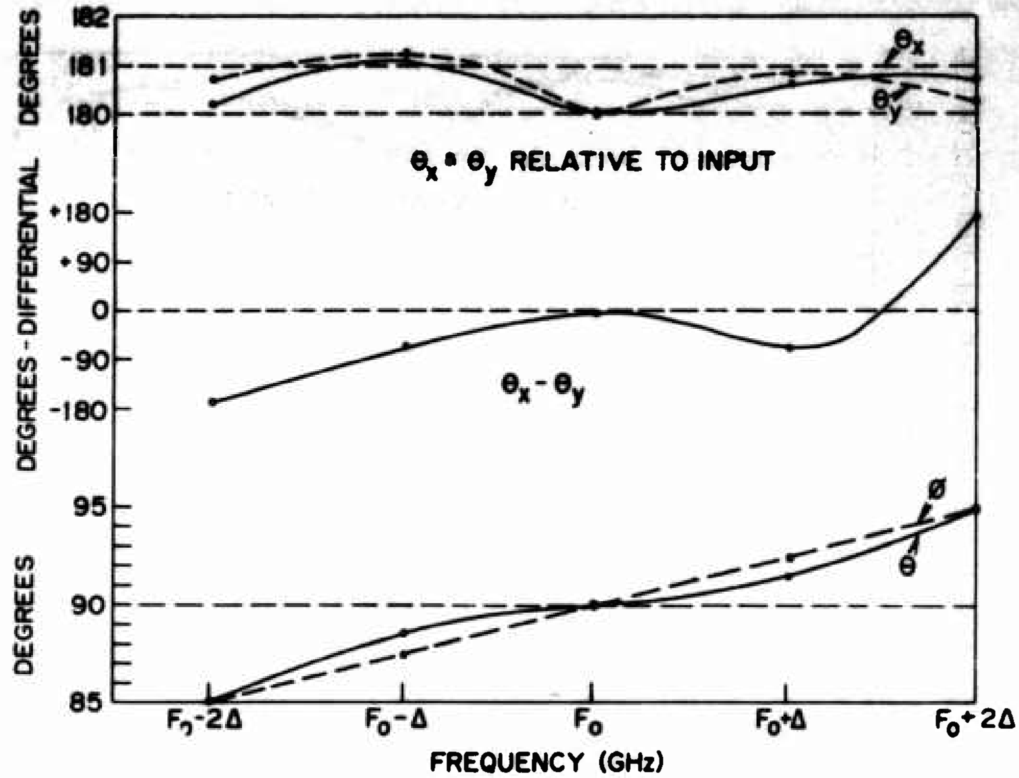


Figure 16. Dual Receiver Polarizer - Case 2

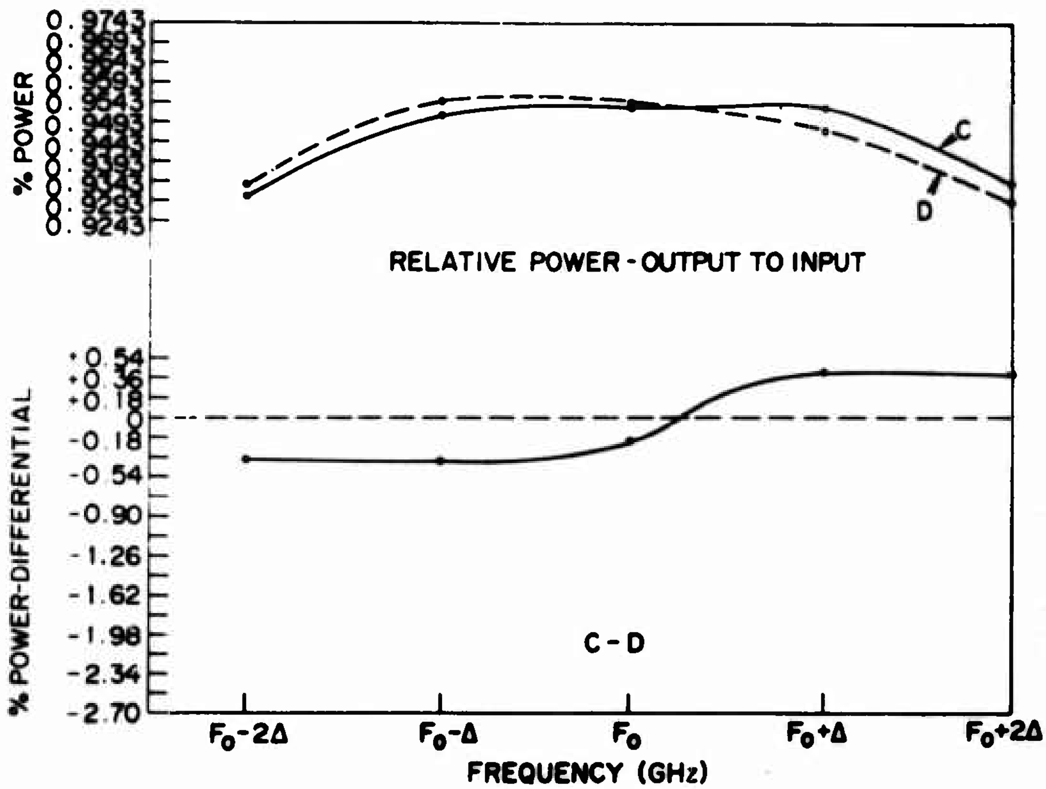


Figure 17. Dual Receiver Polarizer - Case 2

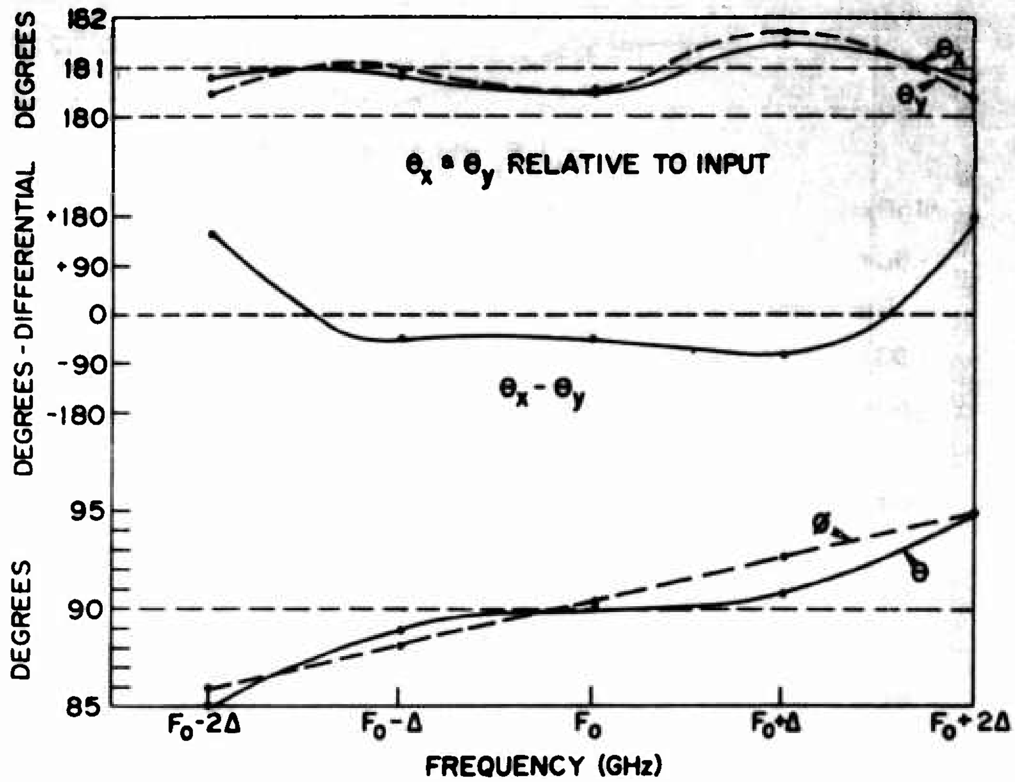


Figure 18. Dual Receiver Polarizer - Case 3

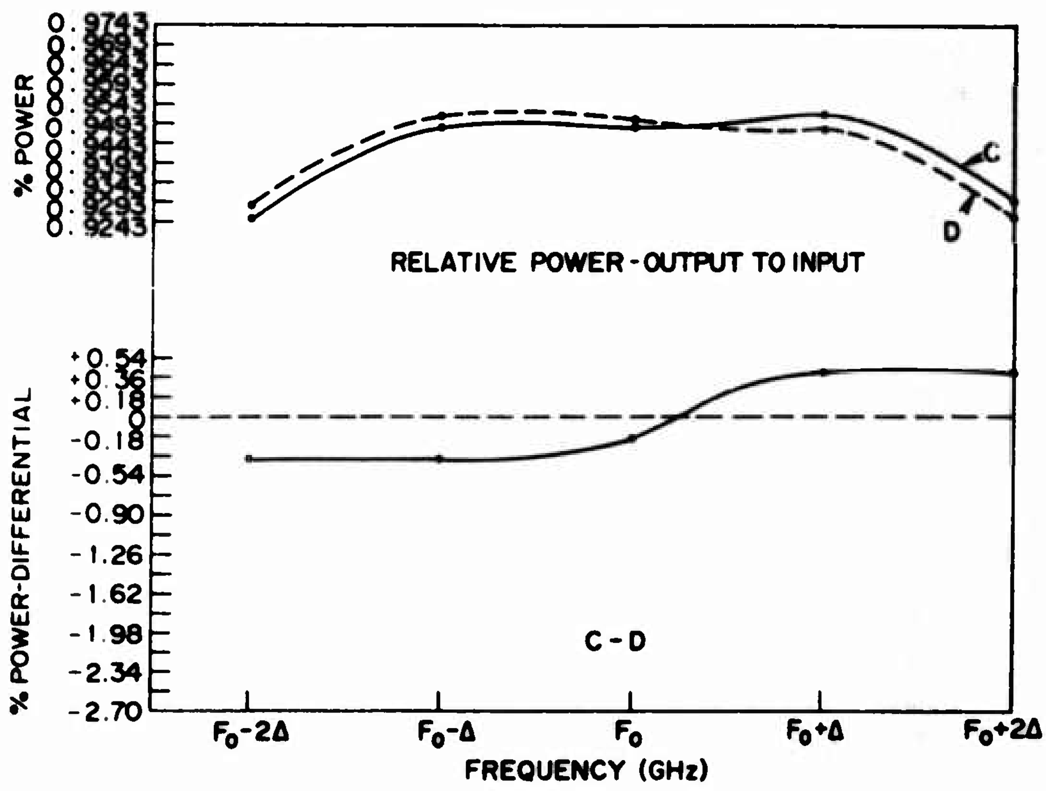


Figure 19. Dual Receiver Polarizer - Case 3

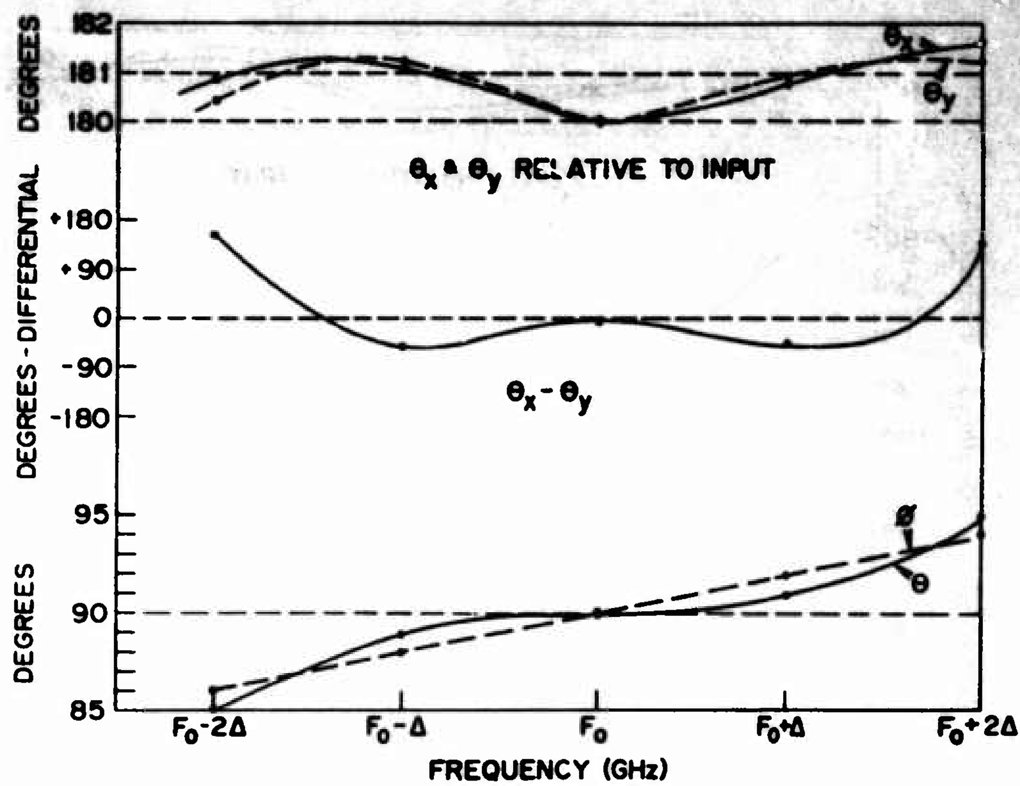


Figure 20. Dual Receiver Polarizer - Case 4

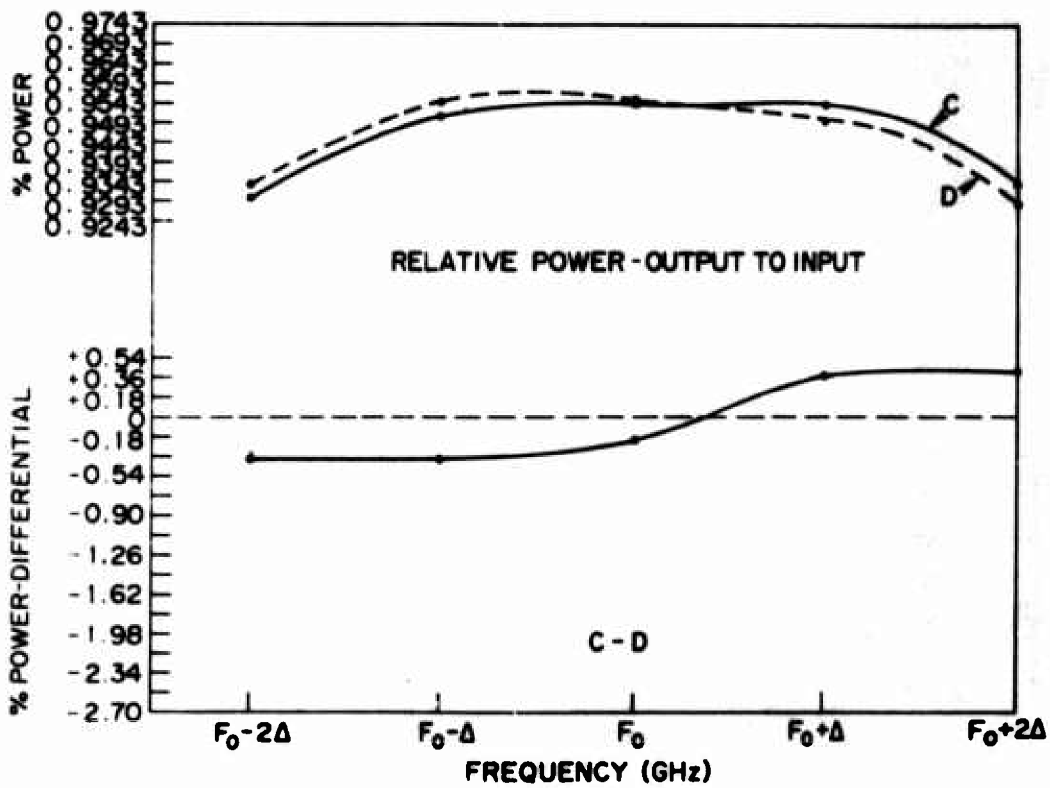


Figure 21. Dual Receiver Polarizer - Case 4

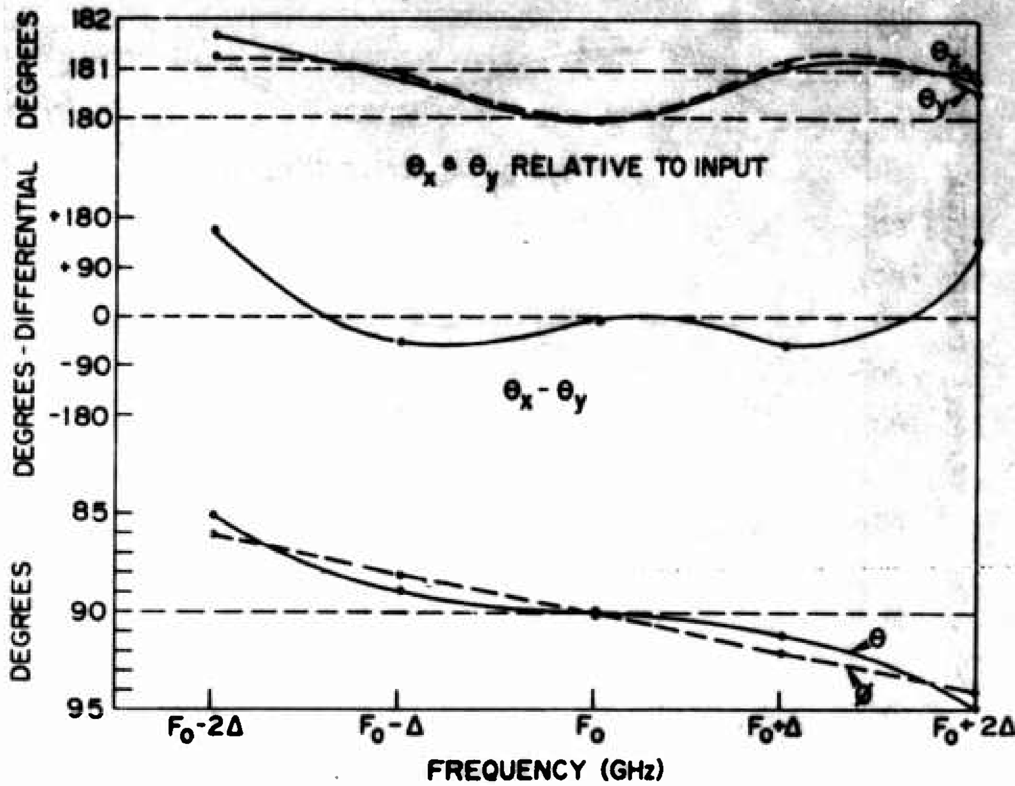


Figure 22. Dual Receiver Polarizer - Case 5

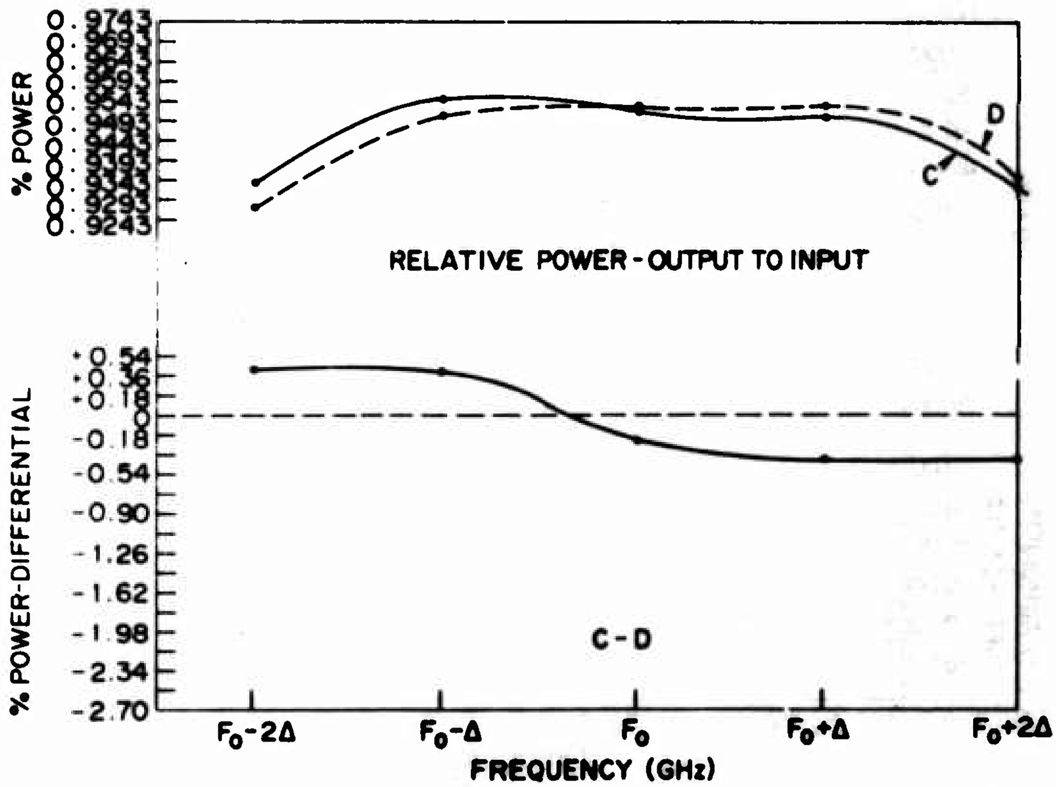


Figure 23. Dual Receiver Polarizer - Case 5

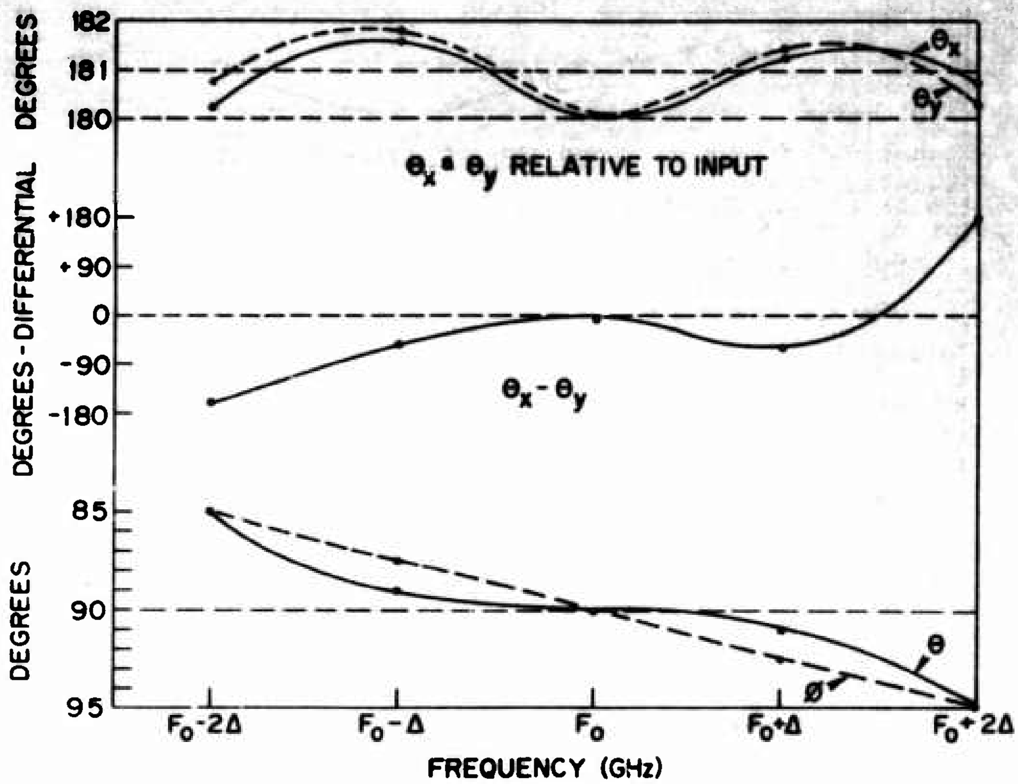


Figure 24. Dual Receiver Polarizer - Case 6

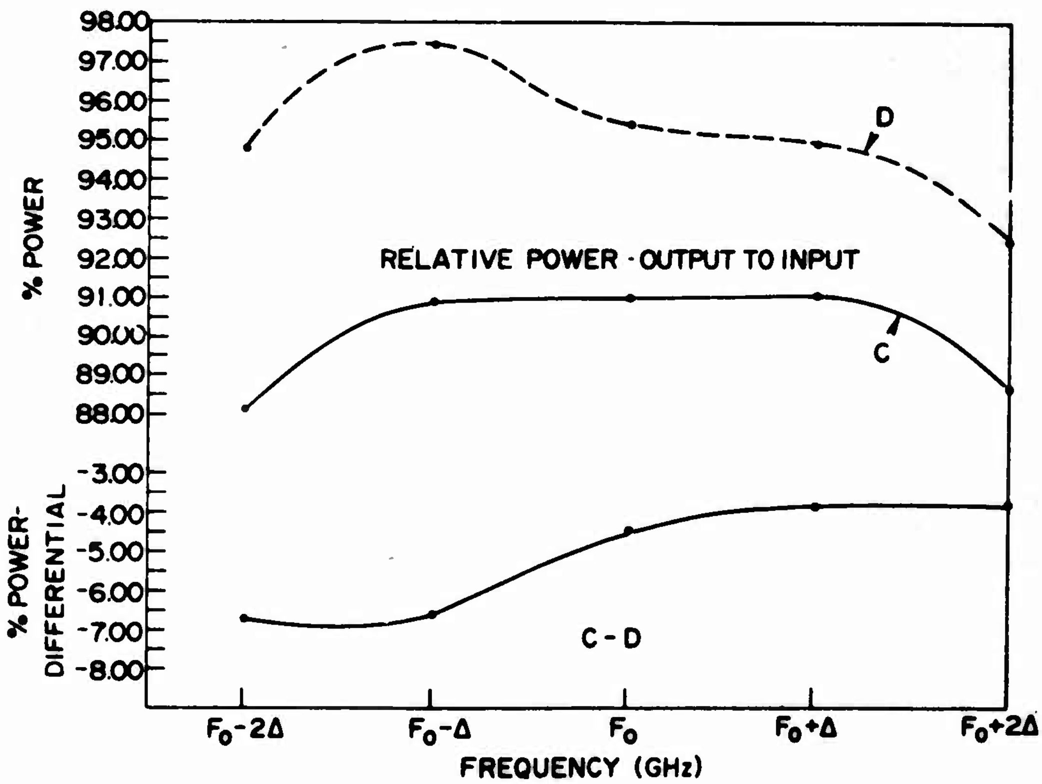


Figure 25. Dual Receiver Polarizer - Case 6

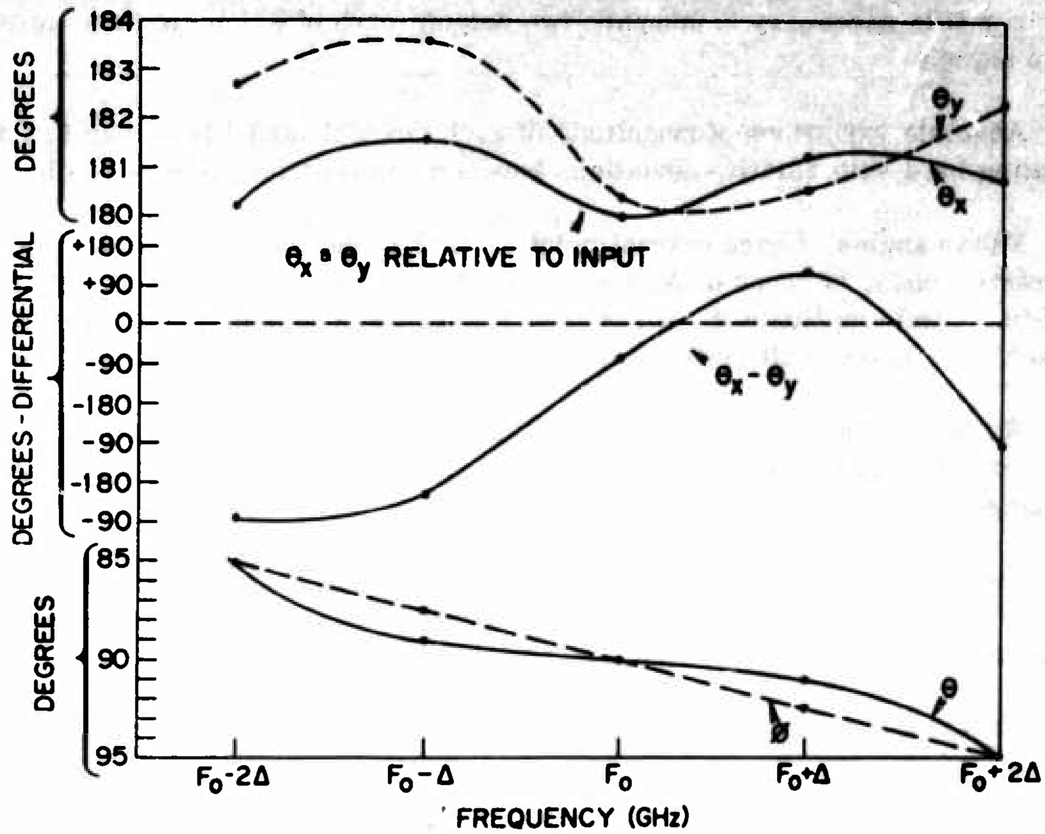


Figure 26. Dual Receiver Polarizer - Case 7

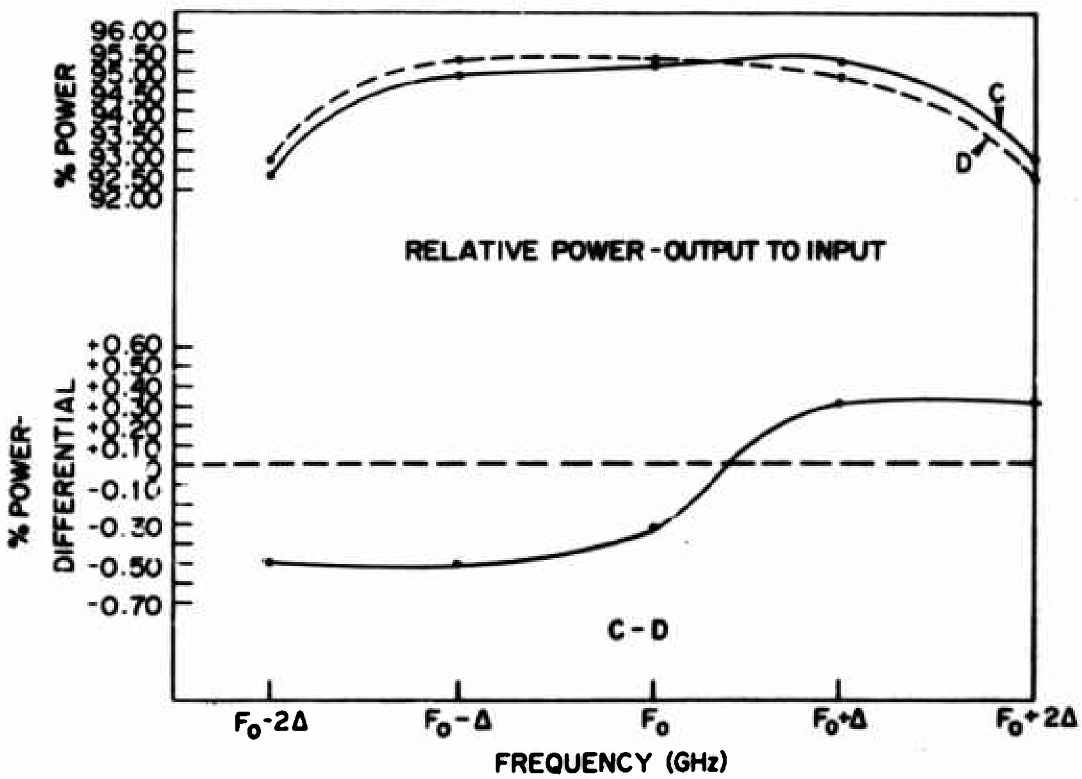


Figure 27. Dual Receiver Polarizer - Case 7

2.2.5.1 <u>Interpretation of Data.</u> Because of the dual receiver output of this polarizer it is necessary to compare two outputs each of which in turn, is the resultant of two signals.

Absolute variations of magnitude of each channel varied less than 0.2 db over the operating band with relative deviations between channels less than 0.02 db.

Phase angles of each channel relative to the input were less than 1.5 degrees and differential phase between outputs was less than 0.5 degrees. The exception to this was the differential amplitude (C - D) of case 6 where a large amplitude error representing an unbalance in the multimode transducer was introduced into the equations.

An interesting result was the fact that an error of phase of the multimode transducer caused only a small error in the differential phase between receive channels and no change in the absolute or relative amplitudes.

Further studies of this system, because of its complexity, will be reserved to a later date when the experimental results of the breadboard design to be tested under this program can be used to advantage for a more accurate evaluation.

2.3 CONTROL AND DRIVE REQUIREMENTS

The polarizers described in Sections 2.2.1 and 2.2.4 both require special drive or command signals. Although the detail discussion of the driver will be reserved for Section VII, a general survey of system needs must be considered at this point.

The polarizer of Section 2.2.4 (dual receiver design) requires 5 commands from some primary system command source. These 5 commands must then be converted to 8 signals to each of the phaser elements.

Because of the latching nature of the phaser element, these secondary commands to the various phasers will take the form of a short duration polarized pulse. The polarity of this pulse will determine the state of each phaser element.

It must also be noted that due to the inability to reproduce garnet materials with precise values of $4\pi M_r$ (thus precise phase shift), it is necessary to incorporate appropriate trimming into the phaser driver for fine adjustment of phase. When a garnet material is not driven into saturation by such trimming, it has been found that repeated application of drive in the same polarity to a phaser will introduce phase error.

Therefore, the network which converts the 5 primary command signals must not only produce the appropriate command signals to the 8 phaser elements but must also determine if a phaser element is already in its desired state, at which point no further command should be supplied.

This distribution circuit is at present under study and precise details must be reserved for the final report on this program wherein details as to the precise nature and recommended location of this network will be clarified. However, information now available is given in Section III of this report.

2.3.1 Configuration

At this time the size of the phaser elements and their driver circuitry has not been fixed. However, some system information can now be supplied.

It is understood that the polarizer will be attached to the movable element of an antenna and will be, at a minimum, partially exposed to its surrounding outdoor environment.

It will probably be necessary, therefore, to protect the polarizer not only from direct outdoor environment (primarily rain) but also to provide some form of temperature stabilization to assure proper polarizer operation. Since these factors at this ti are only speculative, the sketch of Figure 28 is only for the purpose of approximate estimates. It should be noted, however, that the layout of Figure 28 can be folded and shifted relative to the multimode transducer without greatly affecting polarizer performance.

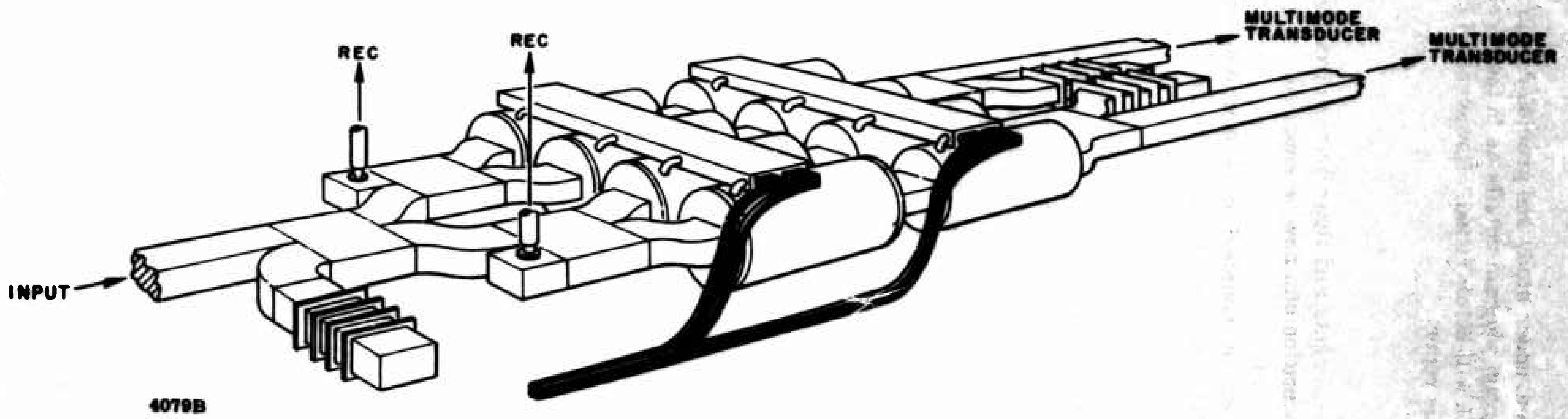


Figure 28. Dual Receiver Output Polarizer - Preliminary Layout

SECTION III

COMPONENTS

3.1 GENERAL

This section has been reserved for discussion of the various components required to construct the polarizer. These components are quite often unrelated but must be considered in relation to the overall polarizer requirement of Section 2.

3.2 PHASER ELEMENTS

The phaser elements as employed in the polarizer of Section 2 are 90 degree non-reciprocal elements. It can be seen that a smaller quantity of 180 degree elements could be employed for this purpose. However, because of construction and ease of assembly and test, the 90 degree element has been chosen as the basic building block.

During the very recent past, great strides have been made in the nonreciprocal latching toroid type of phaser. Because of these recent developments, the large part of the emphasis of this program has been channeled in this direction although all promising leads towards other designs have and will be pursued to determine feasibility for this polarizer application.

3.2.1 Historical Background

It would be proper at this point to review the progress attained over the last two years in phaser design.

Although much theoretical and experimental work was performed before this date, phasers during early 1965 could be described as "Model T's" of the industry. Power handling was confined to relatively low powers and losses for moderate power handling units were in excess of 1.3 db.

A typical example of what could be called "an excellent unit" in the summer of 1965 is given by this X band specification:

Peak Power	20 kw
Average Power	75 watts (maximum bit dropoff 5 degrees with power)
VSWR	1.35
Loss	1.3 - 1.4 db (4 bits)

By mid 1966, this specification had been revised due to further development:

Peak Power	20 kw
Average Power	200 watts (maximum bit dropoff 5 degrees with power)

VSWR	1.25
Loss	1.0 db (4 bits)

This characteristic must be further revised by early 1967 to read:

Peak Power	50 kw +
Average Power	400 watts (essentially flat with power)
VSWR	1.2
Loss	0.80 db (4 bits)

If one considers present technology, it appears feasible that the next generation X band phaser will be capable of:

Peak Power	125 kw
Average Power	600 watts (essentially flat with power)
VSWR	1.2
Loss	0.80 db (4 bits)

It can be seen that the loss and VSWR have been significantly reduced while peak and average power have been significantly increased at X band.

Similar changes in the state of the art have been accomplished at C and S bands.

One significant improvement in phaser design has resulted from the work of Dr. J. L. Allen at Georgia Tech and Sperry Microwave in accurately predicting phaser characteristics from theoretical studies. This has lead to the "optimum" design phaser for typical operation.

3.2.2 Phaser Design

The design of a phaser for high average and peak power must include:

1. Maximum peak and average power
2. Total phaser length available
3. Operating temperature
4. Methods of cooling

The first design consideration is the average and peak power requirements.

The use of boron nitride on beryllium oxide in the phaser design has become paramount in recent design in reducing internal temperatures of the toroids.

Total power loss in a phaser is approximately the same in the three major radar bands — i.e., 1 db in S, C or X bands. Since the phaser size is proportional to wavelength, the dissipation per unit length will be proportional to frequency.

Referring to Figure 29, the use of boron nitride slabs on the sides of the toroids has resulted in a maximum average power dissipation of 5 watts/inch of material for a practical phaser. The use of boron nitride "T" structures has increased this value to approximately 10 watts/inch, with present studies indicating that for extremely accurate toroid-boron nitride fits and the use of improved thermal transfer media between these various materials, this dissipation can be increased to 15 watts/inch.

These values, taken as allowable dissipation per unit length, appear to be independent of the frequency band, assuming similar cross-section of the phaser. These values are also affected somewhat by the temperature of the phaser housing (room temperature for the above values).

The phaser required for the polarizer described herein will now be designed using the above numbers.

Rather than stop at the intermediate specification, let us assume that the polarizer must handle 20 kw average power (full specification). If the polarizer design of Section 2.2.4 is employed, the power to any individual phaser is reduced to 5 kw average, 2.5 Mw peak.

The anticipated dissipation in the toroids of the phaser elements is assumed to be approximately 0.3 db per 90 degree element.

Therefore, the power dissipation, $Pd = 0.065 (5 \times 10^3) = 325$ watts.

If 15 watts/inch dissipation is allowable, then the length must be $\frac{325}{25} = 21.6$ inches minimum.

For convenience in calculations, we will assume a toroid length of 20 inches.

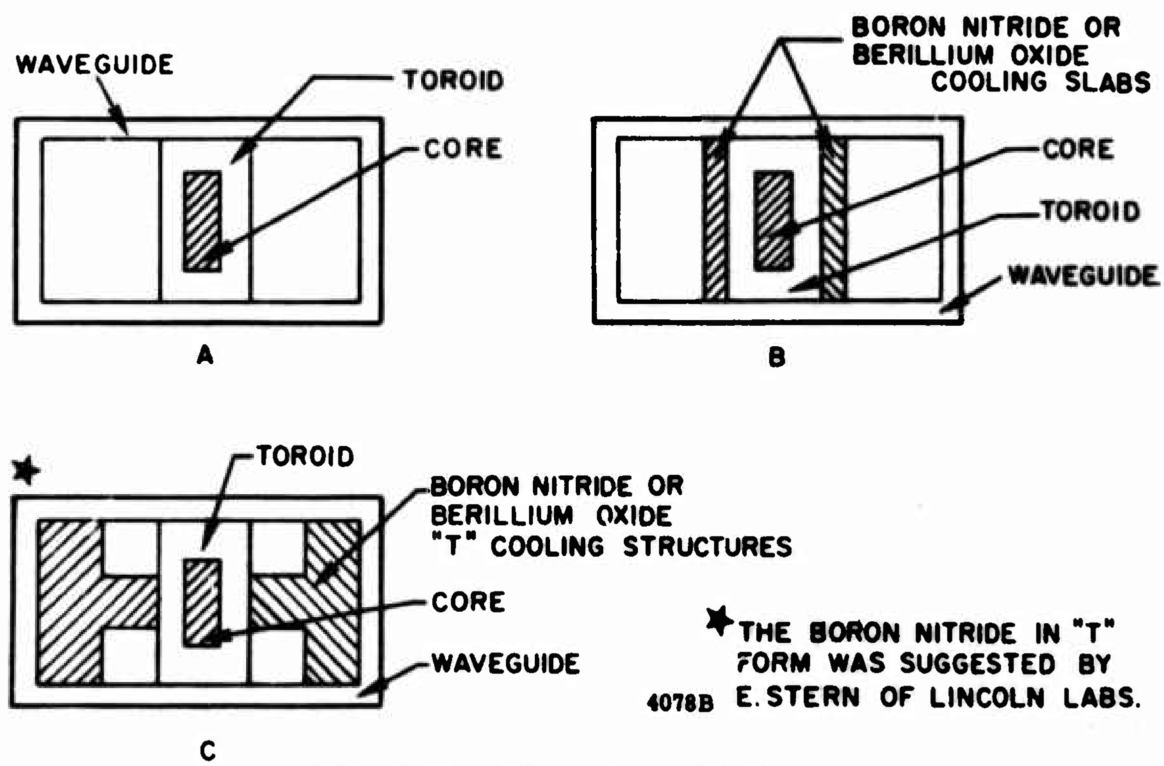


Figure 29. Phaser Cross-Sections

In order to attain 90 degrees phase shift with controlled insertion phase, it appears necessary to choose an untrimmed bit length of 110 degrees minimum. Therefore:

$$\frac{110 \text{ degrees}}{20 \text{ inches}} = 5.5 \text{ degrees/inch}$$

A material with appropriate $4\pi M_s$ to avoid peak power limiting should now be chosen. Referring to Figure 30, it can be seen that a material with 15% gadolinum doping will reach an extremely high limiting threshold with a value of $\frac{\delta 4\pi M_s}{f_c}$ less than 0.280.

The material chosen for present study, Sperry G-518 (YIG = 15% Gd + Al) has a nominal value of $4\pi M_s$ = 275 gauss.

At the lowest operating frequency of 3.1 GHz,

$$M_s = \frac{\delta 4\pi M_s}{f_c} = \frac{2.8(275)}{3100} = 0.248.$$

This value is significantly below the critical M_s value of 0.280; therefore, limiting should not be a critical parameter.

The conventional phase shifter (using the optimum design of J. L. Allen), however, would yield 380 degrees phase shift for a 20 inch active length and a loss appropriately higher.

To attain the low phase shift/inch necessary for reduced loss/inch compatible with the requirements of this polarizer design, it is necessary to reduce the material-rf field coupling. This can be accomplished by:

1. Removing the toroid core (see Figure 29)
2. Reducing the toroid wall thickness
3. A combination of both of the above

If all known factors such as dielectric loss, copper loss, magnetic loss, phase slope with frequency and waveguide cutoff frequency are taken into account, the best design approach appears to be an increase in toroid slot width, the use of a dielectric core, and the use of thin walled toroids. Figure 31 compares this cross-section with the optimum figure of merit design of J. L. Allen.

Results of tests using a design similar to that above are given in Figures 32 through 35. The sample tested was 6 inches long and obviously has a phase shift much lower than desired. (See Figure 34.) This will be remedied by increasing the toroid wall thickness in future tests. The phase shift is flat with frequency over the operating band as seen from Figure 34.

Average power data (see Figure 35) indicates that no significent change in phase shift with average power is evident to 800 watts, the limit of the test facility available.

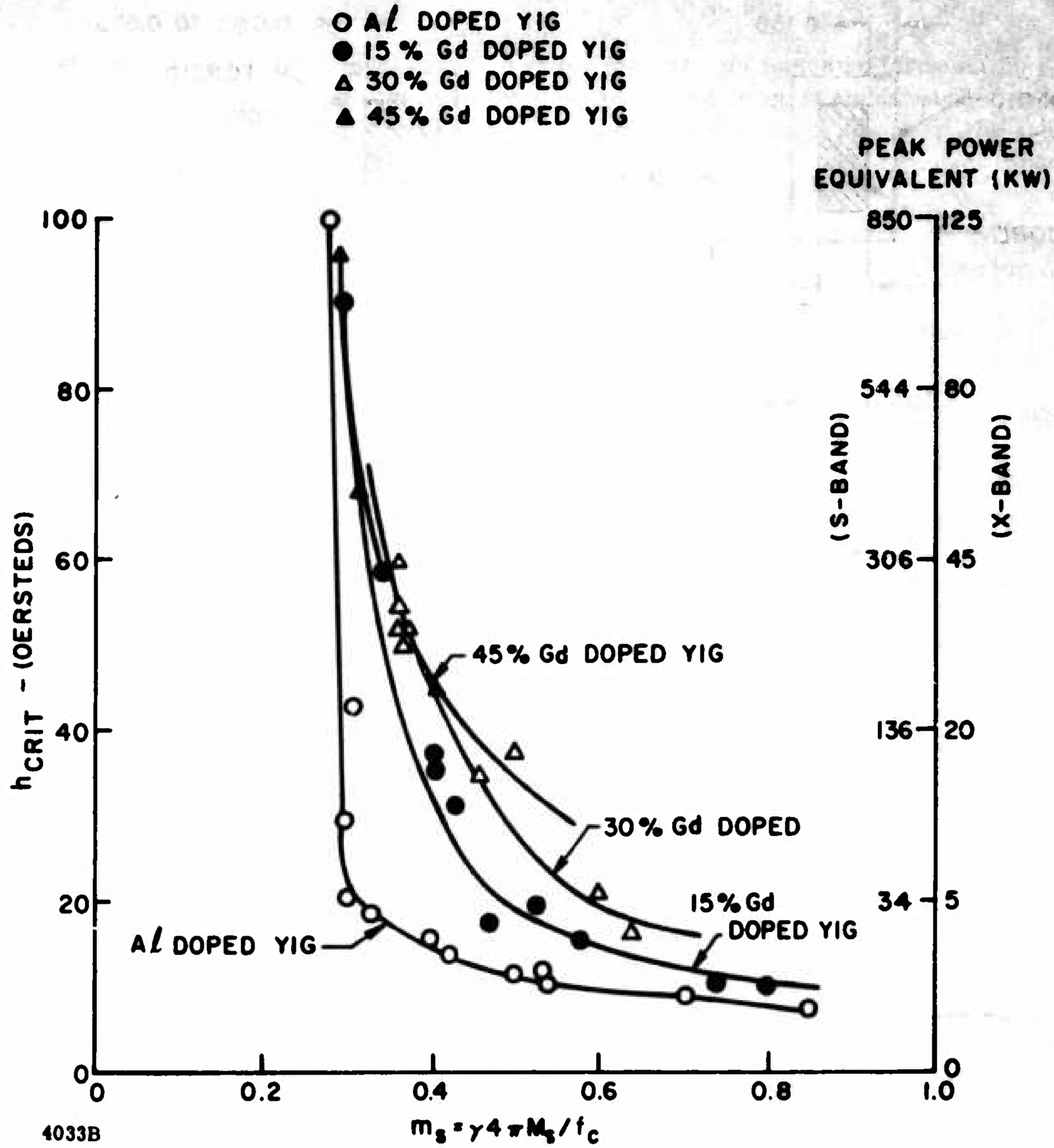
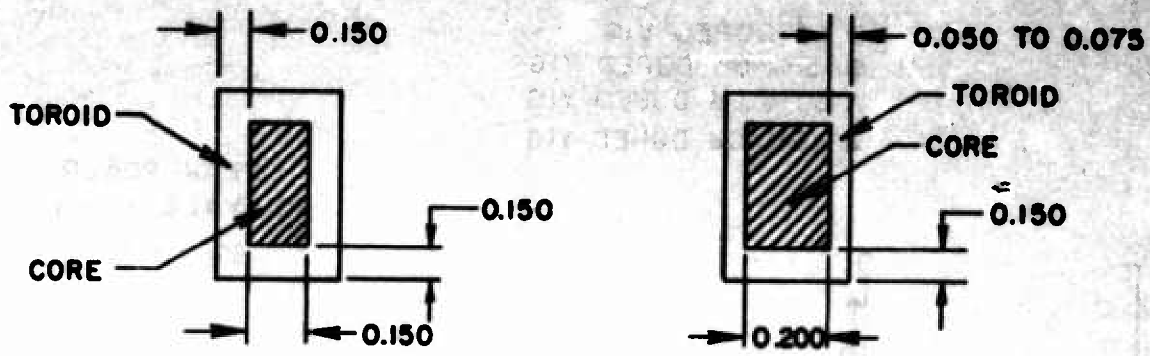
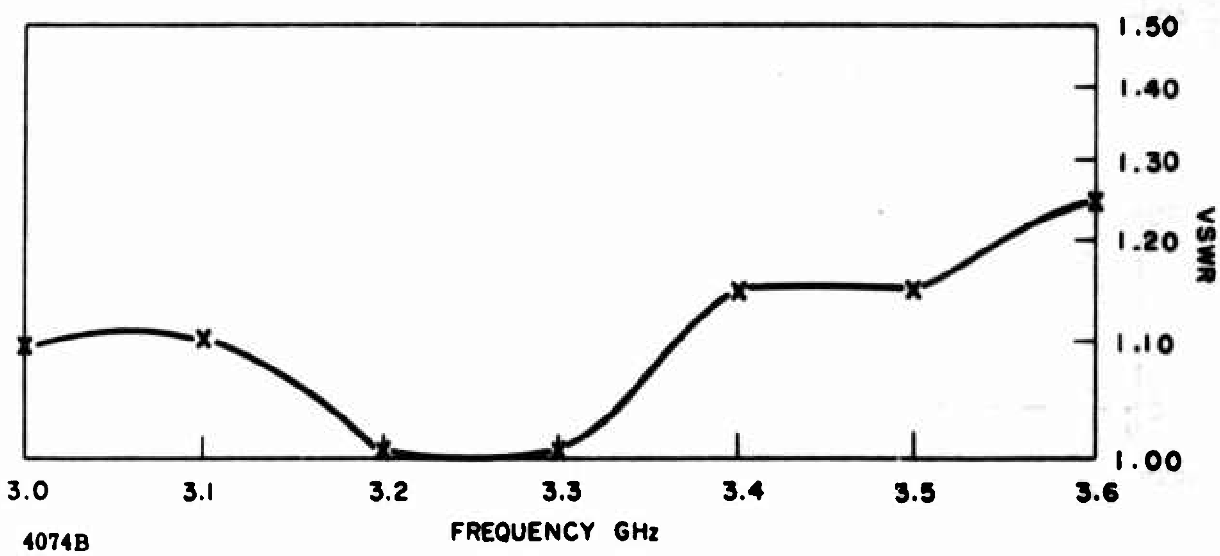


Figure 30. M_s Vs. (h_{crit}) for Various Gd Dopings



4073B CONVENTIONAL HIGH POWER

Figure 31. Conventional Toroid Cross-Section and High Power Cross-Section, S Band



4074B

Figure 32. VSWR Vs. Frequency G-158 Material D-16 Core

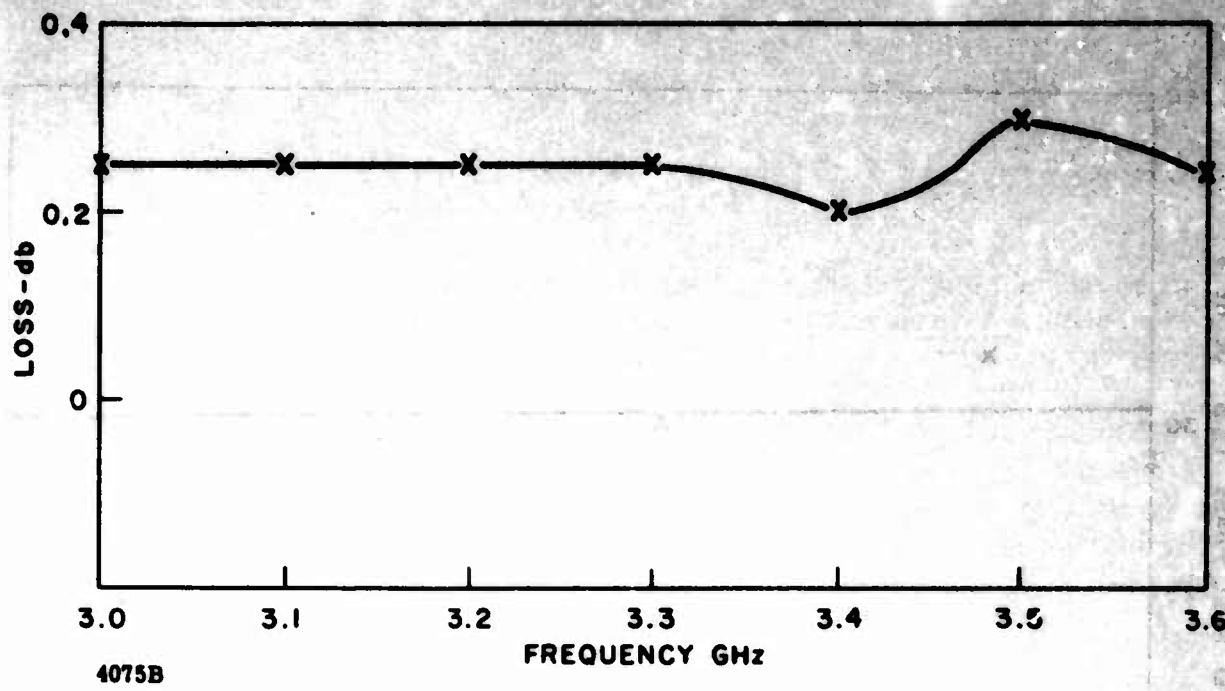


Figure 33. Loss Vs. Frequency

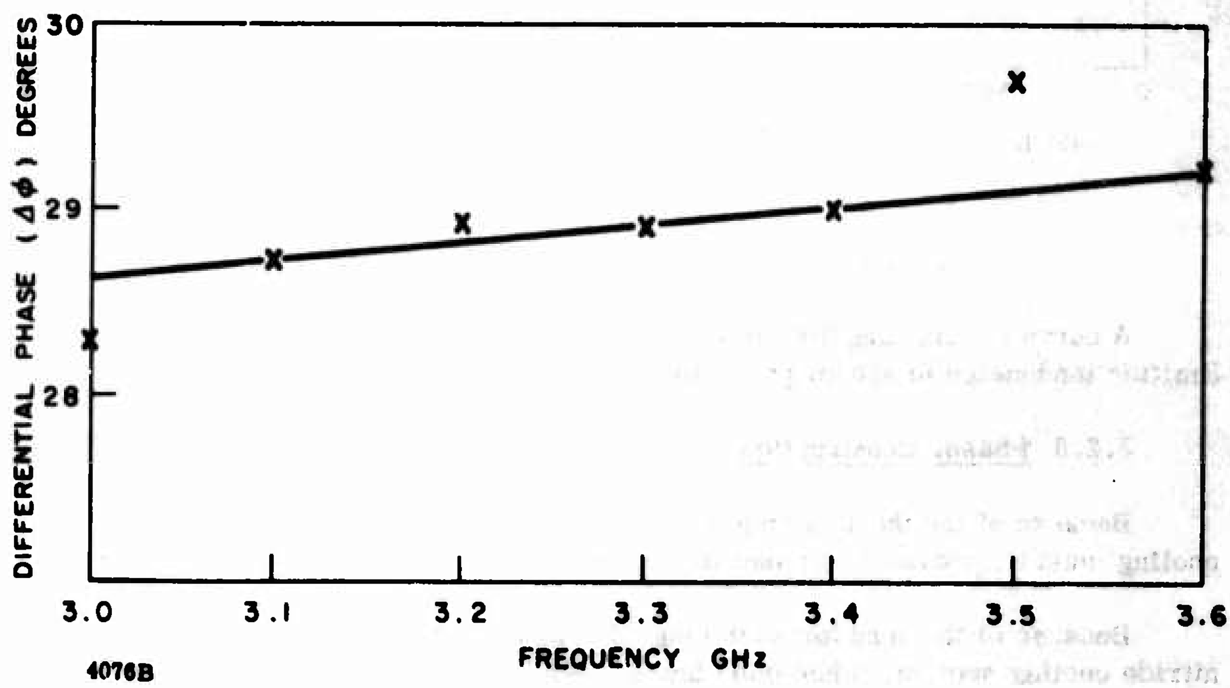


Figure 34. Differential Phase Vs. Frequency

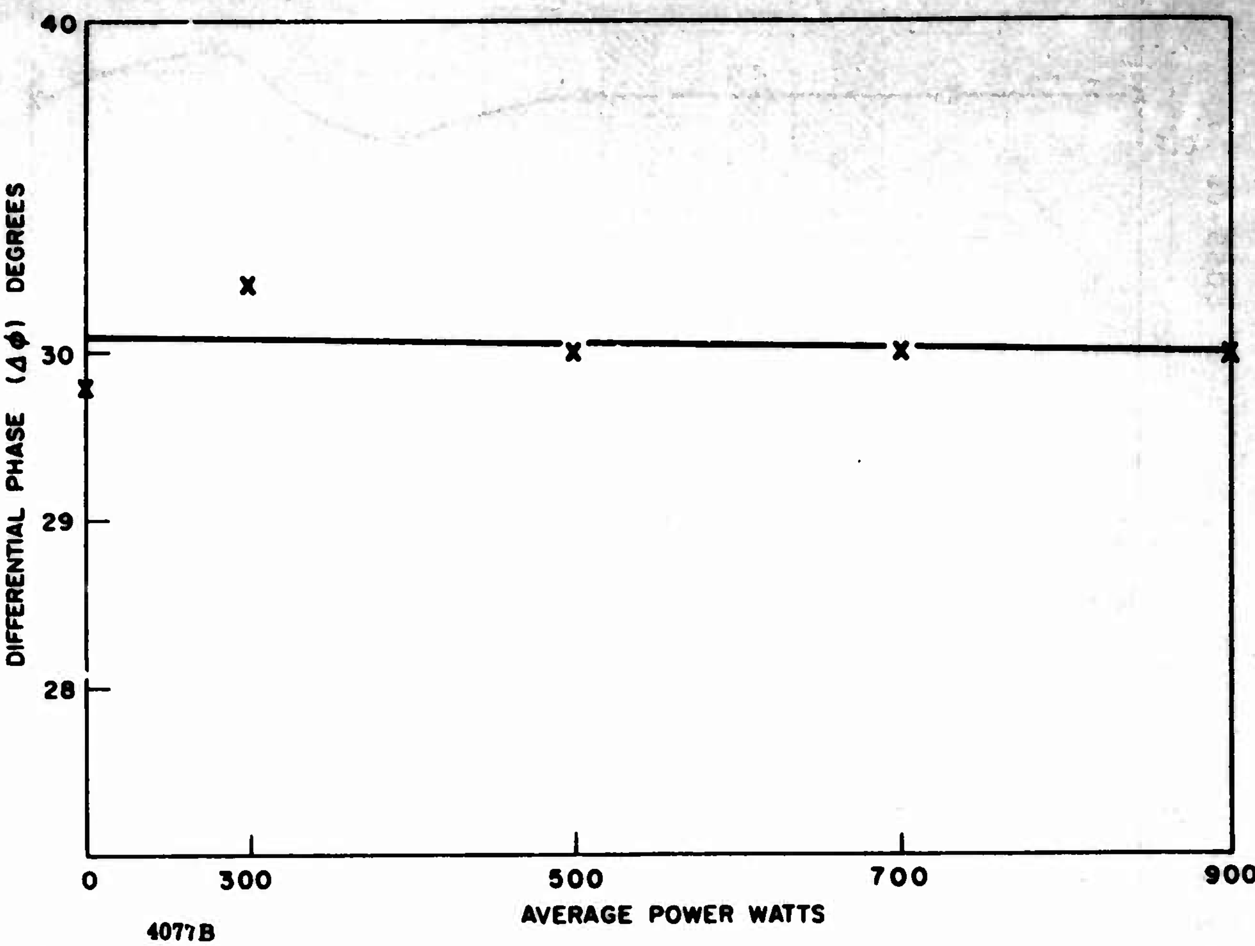


Figure 35. Phase Shift Vs. Average Power

A curve for limiting threshold is notably absent. This material showed no limiting tendencies to 320 kw peak, the upper level of the facilities available.

3.2.3 Phaser Construction

Because of the thermal requirements of the phaser, it has become evident that cooling must be provided as close to the source of heat generation as possible.

Because of the need for switching wire through the toroids and through one boron nitride cooling section, it has been found feasible to construct the phaser out of four separate sections; that is, two side plates, one top and one bottom plate (see Figure 36). The top and bottom plates screw into the side plates, a separate waveguide flange being employed if the conventional round flange hole pattern is employed. Cooling channels for water are provided in each of the side sections.

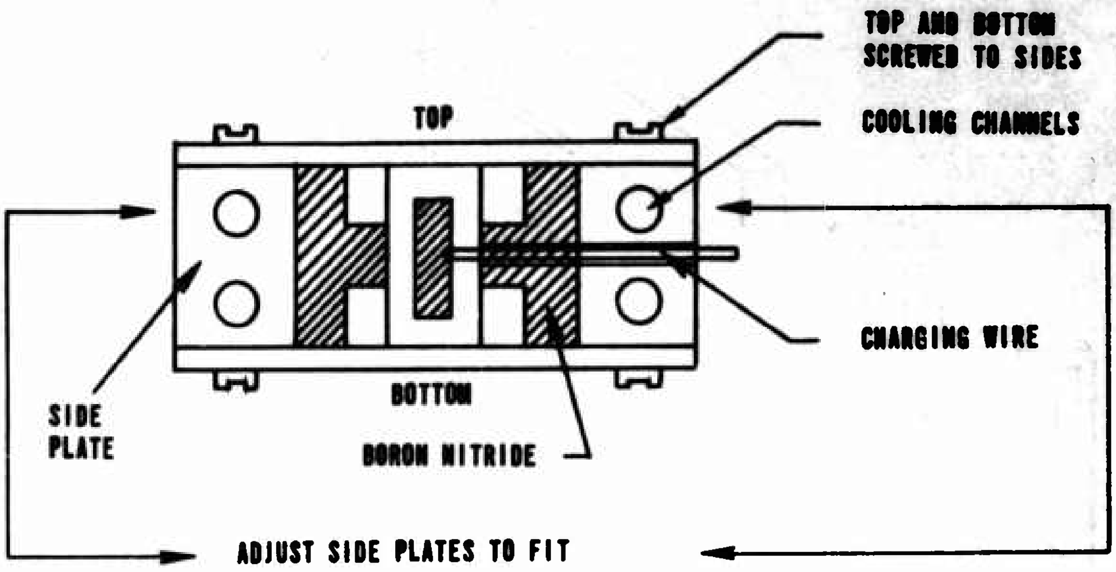


Figure 36. Phaser Cross-Section

Close fit in the plane parallel to the broad wall is attained by adjustment of the side waveguide sections. Fit on the height is attained by proper honing of the side sections to a precision fit with the toroids.

To assure proper fit, all toroids for a single phaser will be precision ground as a set.

It should be noted that at present a single core is used with all toroids placed on this single core. (See Figure 37A.) This stems from the need for cavitroning the toroid slots because of their large size. Toroids therefore can be no longer than 0.5 inches. When longer toroids are used, it will be feasible to use individual core sections of the same lengths as the toroids. (See Figure 37B.)

Further toroid manufacturing techniques will be discussed in a later section.

Because of the overall system need for pressurization, all waveguide seams will be adequately sealed. Techniques for attaining this sealing are now under study and include gasketing and the use of epoxies.

To assure overall environmental protection the external surfaces of the unit will be appropriately treated or protected by an environmental shield.

3.2.4 Environmental Stability

To assure proper operation over the operating environmental temperature range of -22°C to +49°C, the waveguide housing temperature must be isolated from this environment.

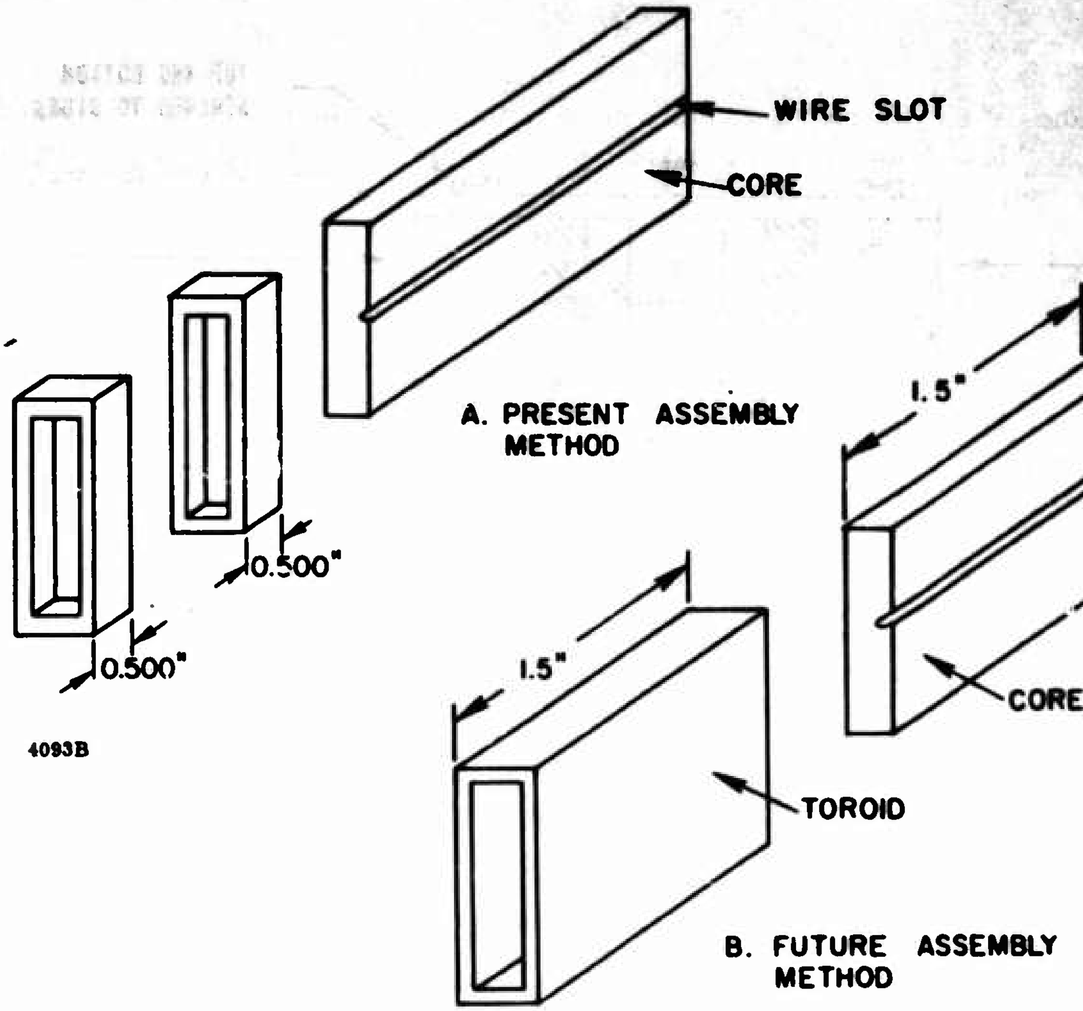


Figure 37. Toroid Core Assembly

It has been found that this can be adequately assured by supplying a coolant closely controlled in temperature. This coolant for lab use is tap water at room temperature. Present studies indicate the need for coolant temperature control of ±5°C to assure adequate phaser performance.

For operational use this water coolant will probably require modification by the addition of an antifreeze agent to prevent system damage when the system is "off".

3.2.5 Toroid Manufacture

It has been found that there is a practical upper limit to the hole size that can be pressed directly into a garnet material. This limit is due to the noncompressibility of the mandrel used and lamination of the garnet material under pressure. The lamination is a result of linear pressures being applied to the garnet powder rather than uniform pressures on all surfaces simultaneously. Therefore, at present it is necessary to produce the garnet material in bar form for toroids of the size required for this program. These bars must be cavitroned and sliced into toroids.

An isostatic press is now being used to press large toroids directly. At present, however, pressing by this method is in its study phase, with useful toroids for phaser application several months from reality.

3.3 HYBRIDS

Studies of the system parameters as described in Section 2 indicate that standard hybrids capable of pressurization and high peak power operation will be adequate for polarizer use.

It appears, however, to be an advantage to overall predicted performance to employ matched hybrids in the polarizer.

Discussions of hybrid characteristics with possible suppliers indicate that matching of coupling and phase characteristics is feasible.

3.4 DRIVER AND ASSOCIATED ELECTRONIC CIRCUITRY

Sperry has developed a productized driver whose basic design is used on this project. Figure 38 shows a block diagram of the proven latching type drivers, the pulse shaping network and isolating stages on each input to isolate the driver from the pulse generator. This driver is a single wire input and output unit. In this driver, all parameters are being optimized for peak current, minimum rise time and minimum power. The output current to the ferrite load is bidirectional and its direction of flow through the load is dependent upon the polarity of the input pulse.

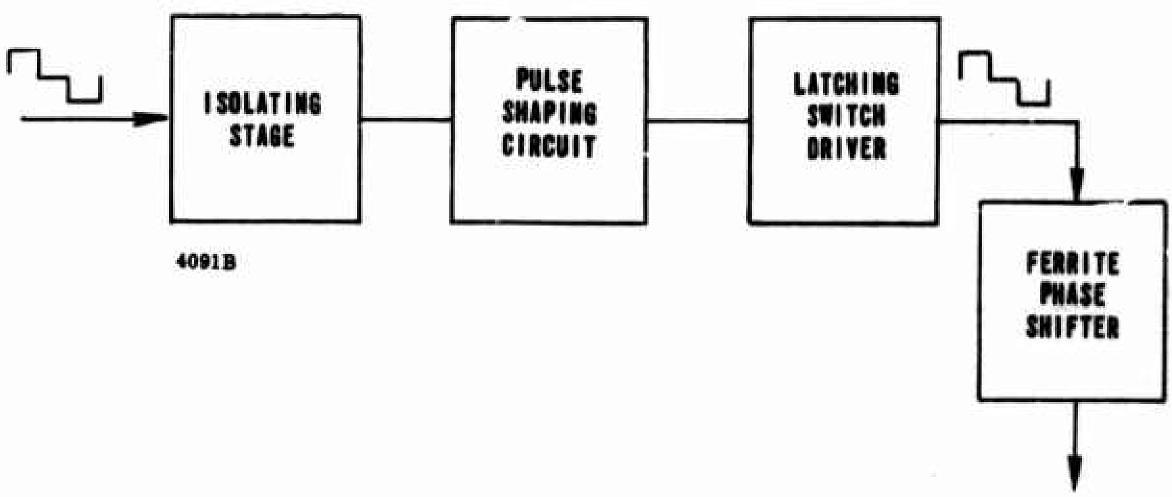


Figure 38. Phase Shift Driver, Block Diagram

The schematic diagram of the phase shift driver is shown in Figure 39. The input signal consists of a positive and negative input pulses approximately each 10 volts in amplitude. The negative gate pulses trigger the upper bank of transistors into conduction and generate a current pulse through the ferrite's charging wire towards ground. Similarly, the negative gate pulses trigger the lower bank of transistors; this results in a current pulse flowing through the toroid charging wire in the reverse direction. The two current pulses alternately change the ferrite to (+) $4\pi M_s$ and (-) $4\pi M_s$, respectively. In this driver, trimmer resistors have been added to limit and set the two output pulse currents to the desired level. It was determined that with the

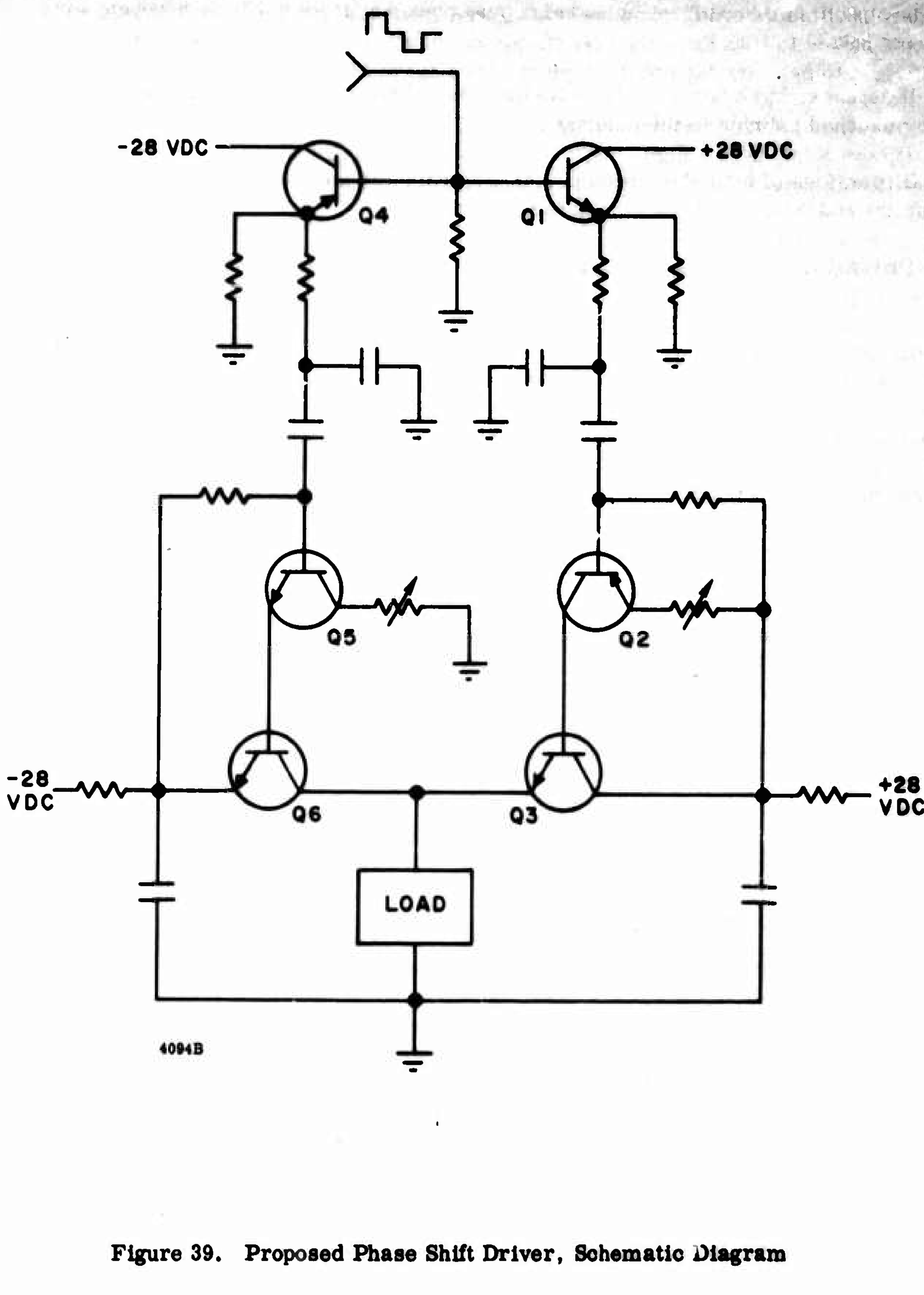


Figure 39. Proposed Phase Shift Driver, Schematic Diagram

large amount of ferrite material used, that the input pulse would be shaped to reduce the back emf developed in the ferrite load. Without the wave shaping network, the back emf developed would break down the transistors. The pulse shaping circuit reshaped the input pulses to turn the output transistor off slowly, allowing the energy in the ferrite load to be dissipated without generating a large back emf.

This basic driver has proven its reliability and utility by demonstrating switching in S, C, and X bands in a highly satisfactory fashion. It has been operated continuously at a switching rate of 10 KHz with the output transistors heat-sinked.

A recent 4-bit driver which is actually in use on an X band phase shifter is shown schematically in Figure 40 and the layout of the printed circuit board is shown in Figure 41.

3.4.1 Logic Circuitry

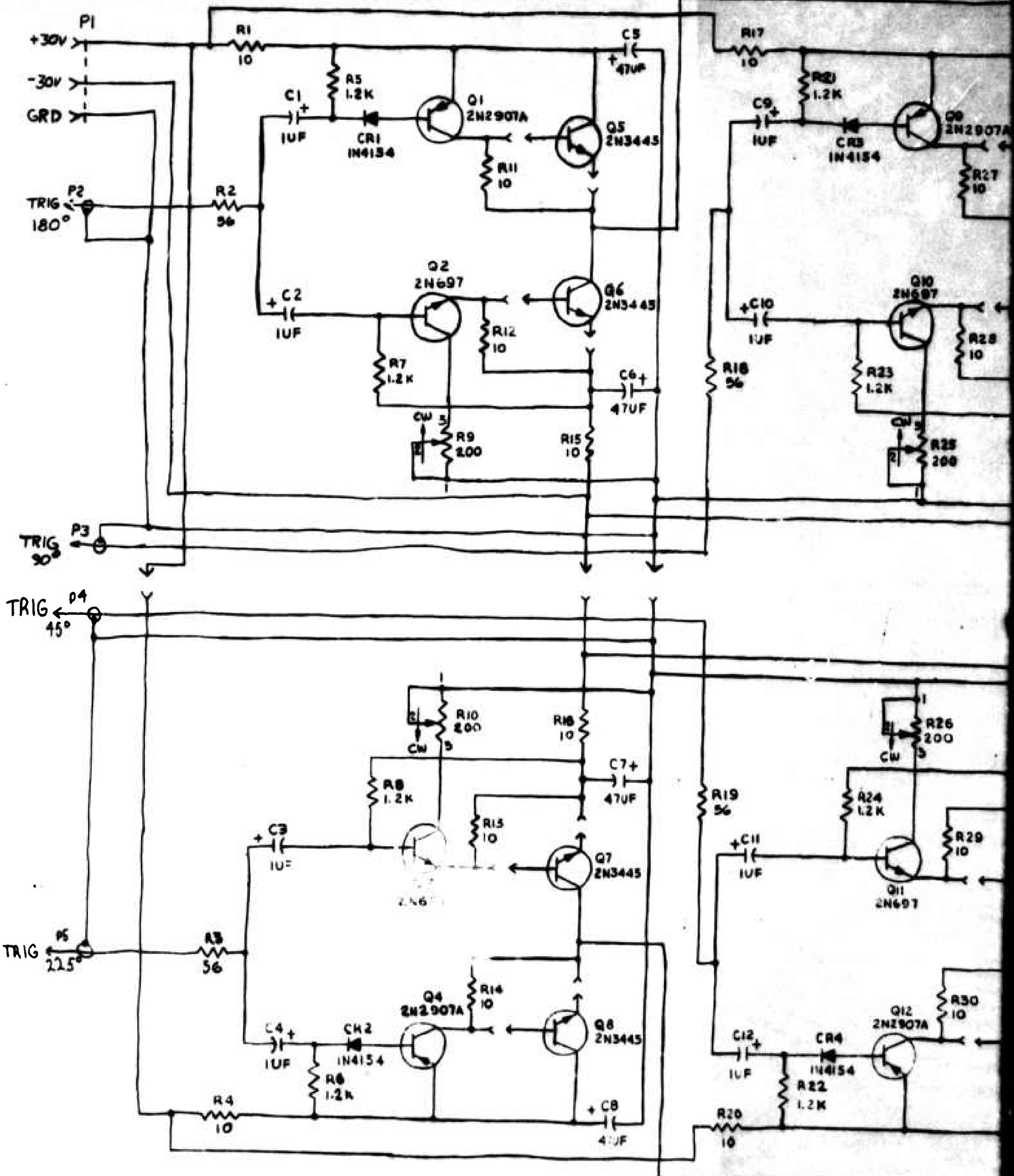
The logic circuitry is shown in Figure 42. The logic circuitry is basically subdivided into eight modules, each module to feed signals to a phase shift driver. The logic receives one of five command signals in the form of a positive pulse. The commands are Horizontal Polarization, Vertical Polarization, Right Hand Circular, Left Hand Circulator, and Receive. For example, if the receive channel is to be activated, the Receive line feeds a positive pulse to each of the eight logic modules.

Each module consists of a matrix steering diode unit and a generating unit. The matrix steering diodes will pass the pulse to the pulse generating circuitry only if the phase shifter has to change states. If the phase shifter is already in the correct state, the matrix unit will shunt the command pulse to ground. If the matrix steering diodes pass the pulse to the flip-flop, it will change states and will provide a trigger pulse to the monostable multivibrator through appropriate diodes. The one shot will generate either a positive or negative pulse to feed the phase shift driver which changes the state of the ferrite load.

For each module the matrix diode unit will determine if the phase shifter has to change state in order to complete the command; the pulse generating circuitry will determine the polarity of the pulse to the phase shift driver.

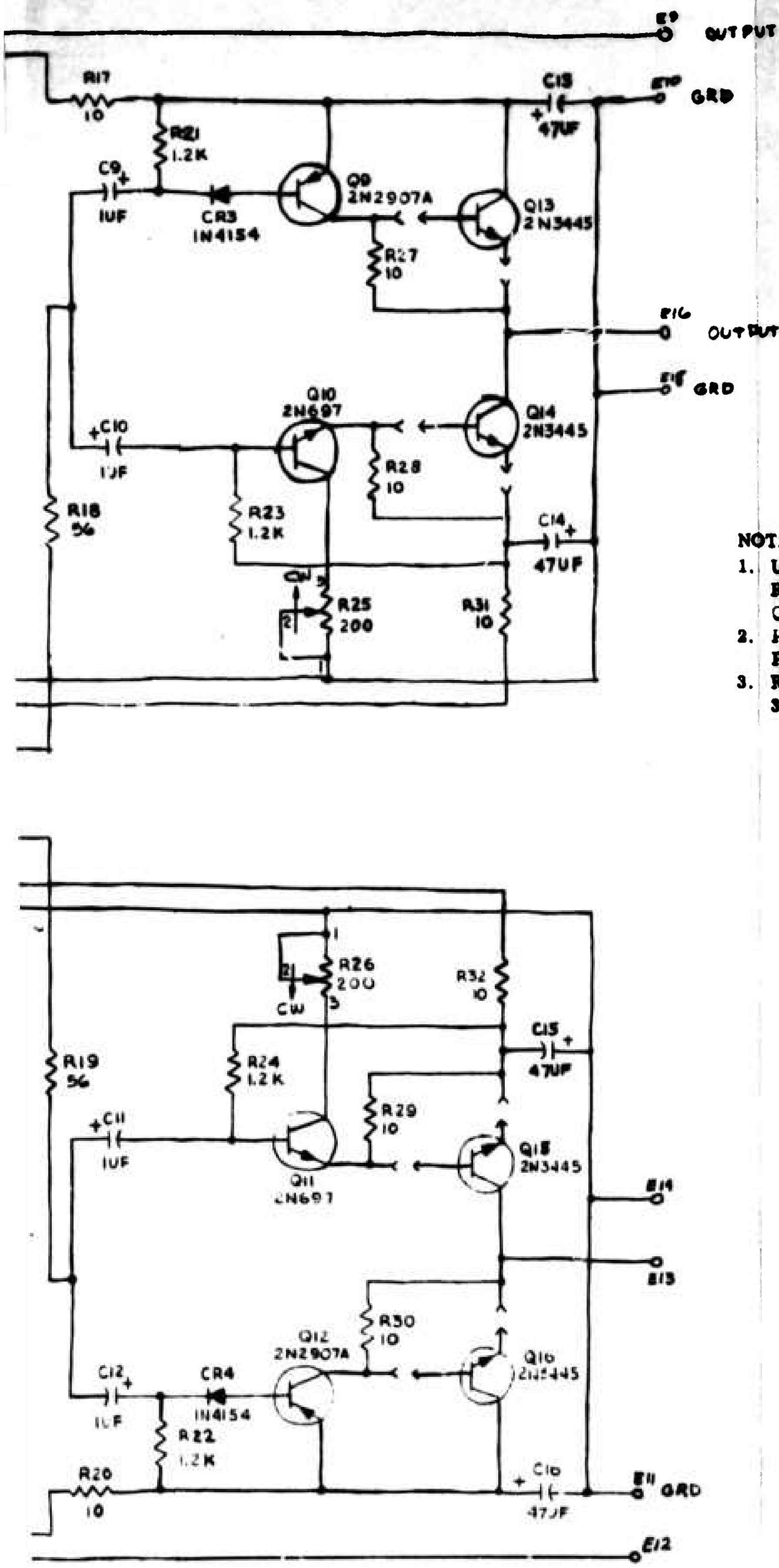
The modules are a small compact package due to the use of integrated circuits in both the matrix diode unit and the pulse generating unit.

The logic circuitry will have almost no loading effect on the command signal drive circuitry, due to the low level input required by the module's input multivibrators.



P1
+30V
-30V
GRD
TRIG
180°
P2
R1
10
R2
56
R5
1.2K
C1
1UF
CR1
1N4154
Q1
2N2907A
Q5
2N3445
R11
10
C5
47UF
Q2
2N697
C2
1UF
Q6
2N3445
R12
10
R7
1.2K
C6
47UF
R9
200
CW
R15
10
P3
TRIG
90°
R17
10
R21
1.2K
C9
1UF
CR3
1N4154
2N2907A
R27
10
R18
56
C10
1UF
Q10
2N697
R28
10
R23
1.2K
R25
200
TRIG
45°
P4
R10
200
CW
R16
10
C7
47UF
R8
1.2K
C3
1UF
R13
10
Q7
2N3445
P5
TRIG
22.5°
R3
56
R14
10
Q4
2N2907A
C4
1UF
CR2
1N4154
Q8
2N3445
R6
1.2K
R4
10
C8
R26
200
CW
R19
56
R24
1.2K
C11
1UF
R29
10
Q11
2N697
R30
10
Q12
2N2907A
C12
1UF
CR4
1N4154
R22
1.2K
R20
10

1

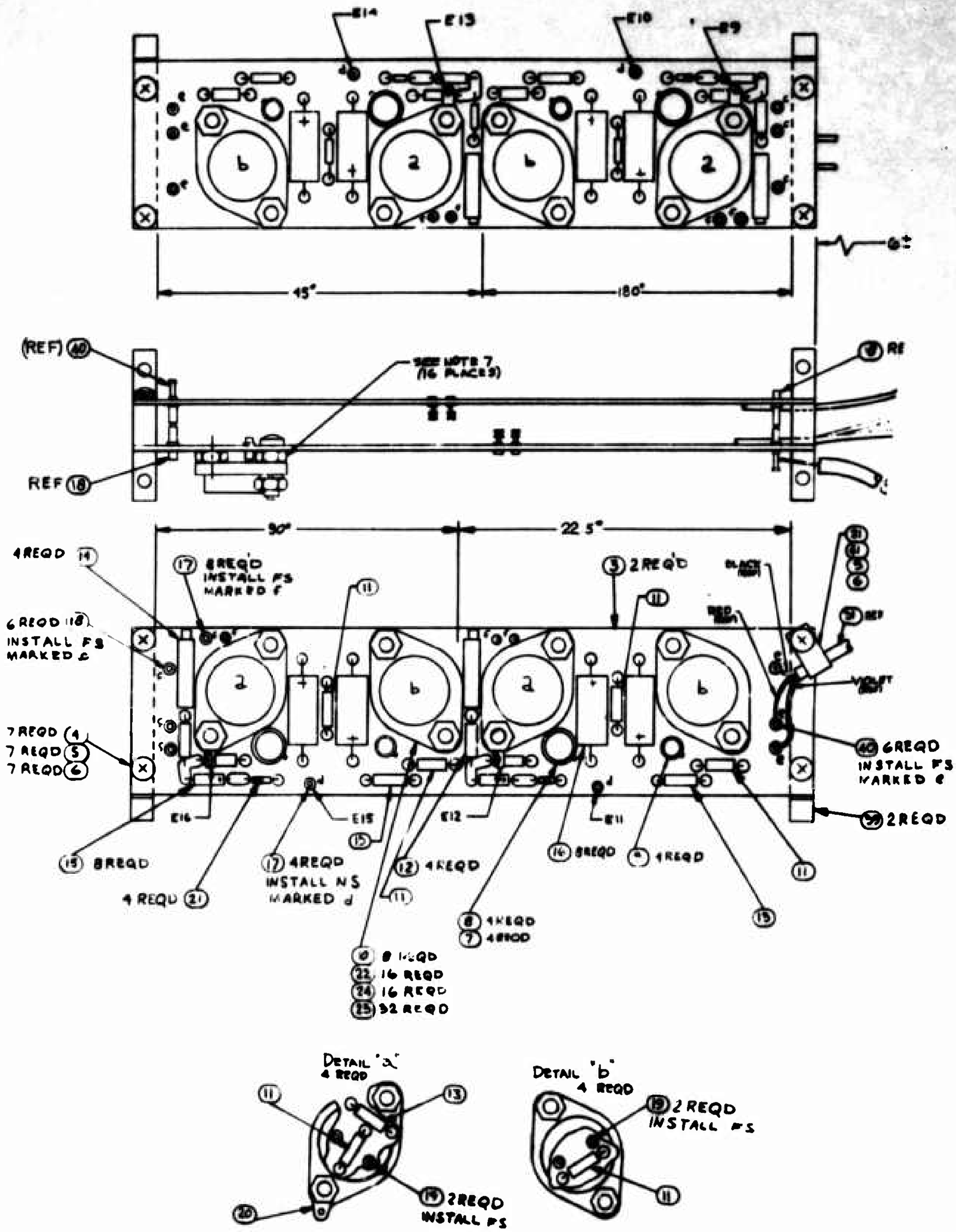


NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   RESISTANCE VALUES ARE IN OHMS.
   CAPACITANCE VALUES ARE IN PICOFARADS.
2. PARTIAL REF DESIG ARE SHOWN: FOR COMPLETE DESIG, PREFIX WITH UNIT NO. OR SUBASSEMBLY DESIG (S).
3. REF DRAWINGS:
   3.1 ASSEMBLY OF PHASE SHIFT DRIVER (X BAND)

Figure 40. 4-Bit X Band Phase Shift Driver, Schematic Diagram

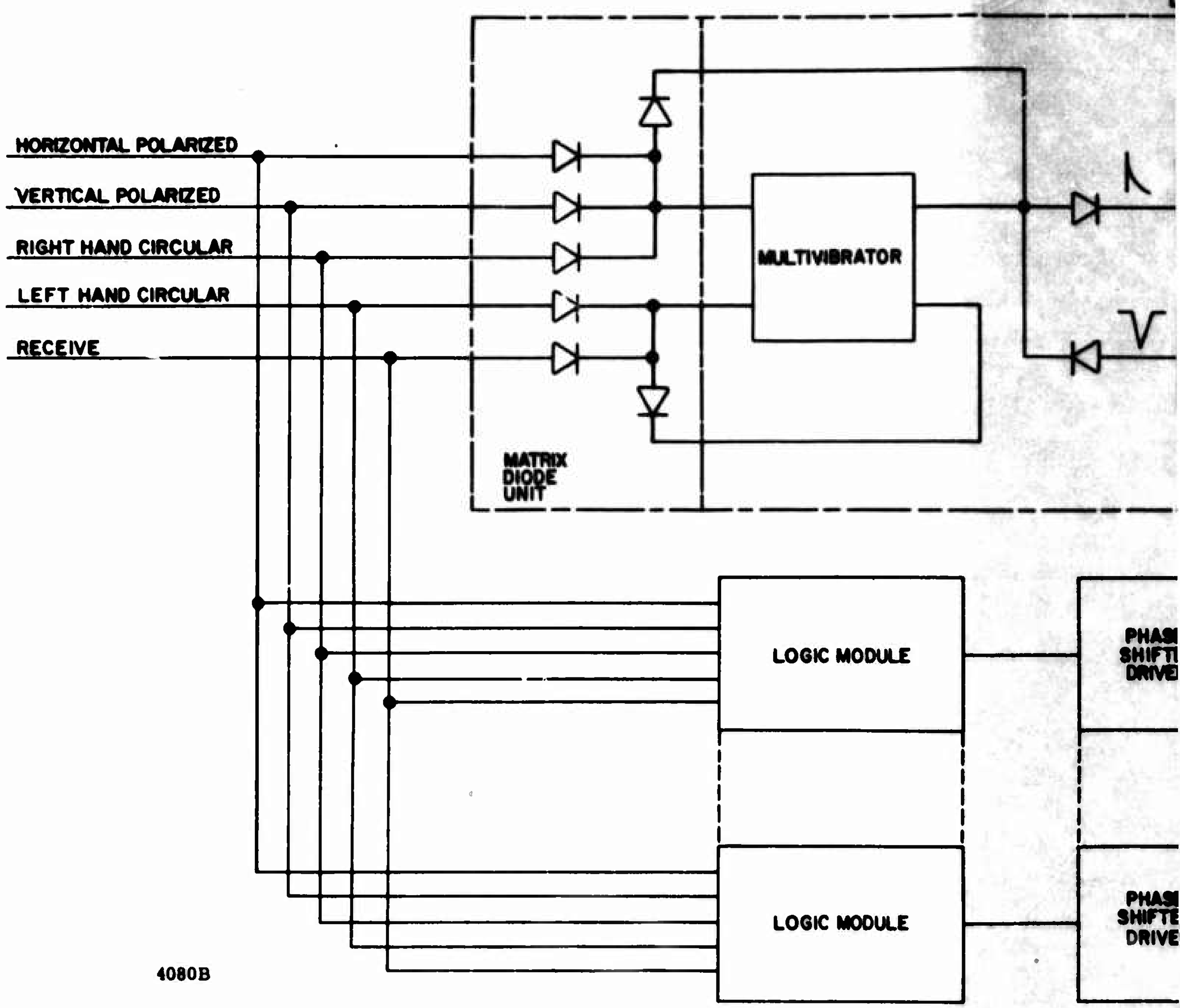
2



NOTES:

1. SOLDER ALL CONNECTIONS PER ITEM 27.
2. ASSEMBLE PRINTED WIRING BOARD PER ITEM 28.
3. SCHEMATIC DIAGRAM AS PER ITEM 26.
4. INTERPRET DRAWING IN ACCORDANCE WITH ITEM 28.
5. LOWER CASE LETTERS ARE FOR REFERENCE ONLY
6. "E" NUMBERS SHOWN FOR REFERENCE ONLY.

Figure 41. 4-Bit X Band Phase Shift Driver, Printed Circuit Board Layout


HORIZONTAL POLARIZED
VERTICAL POLARIZED
RIGHT HAND CIRCULAR
LEFT HAND CIRCULAR
RECEIVE
MULTIVIBRATOR
MATRIX DIODE UNIT
LOGIC MODULE
LOGIC MODULE
4080B

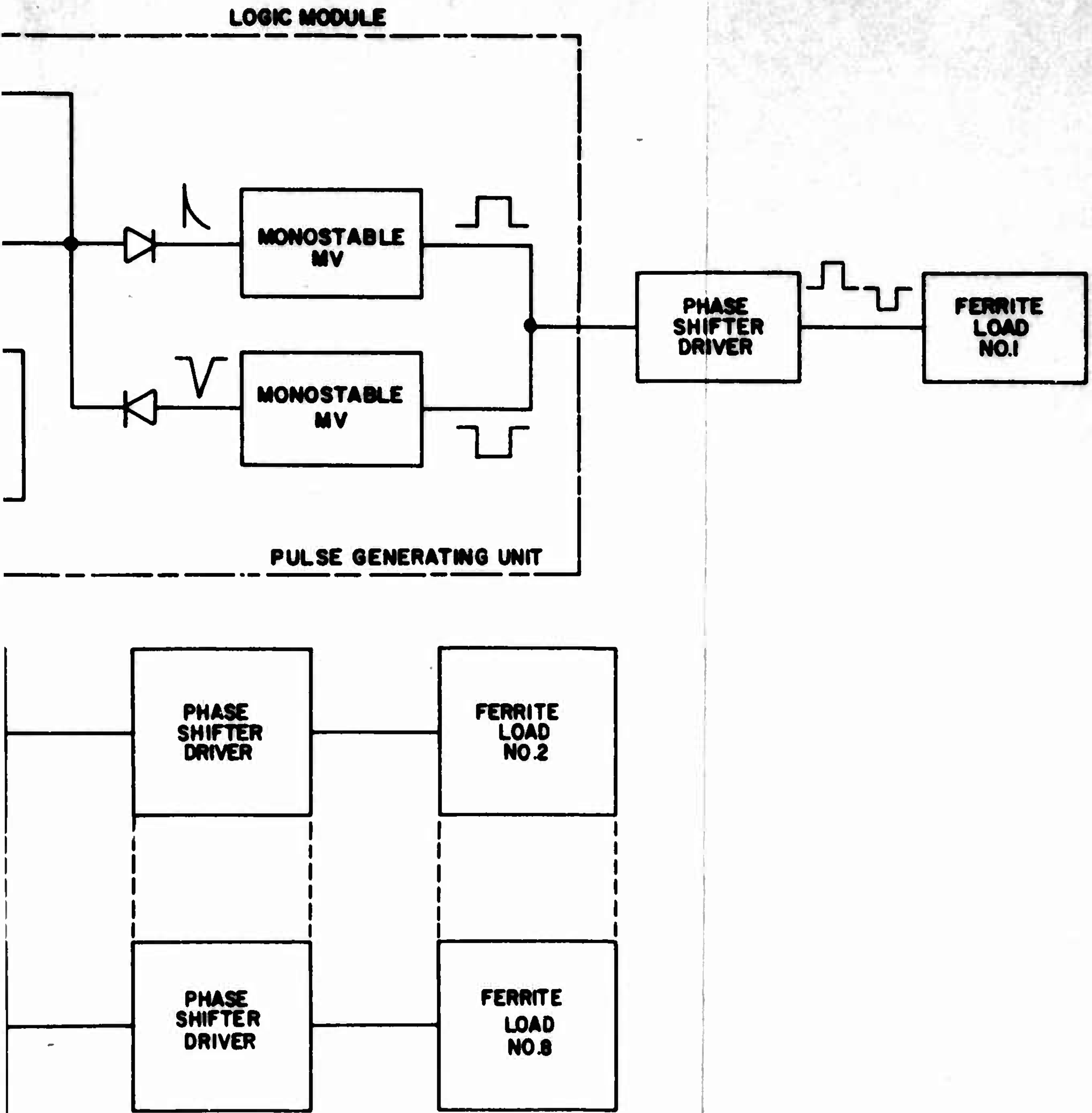


Figure 42. Phase Shift Driver, Logic Circuitry

2

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The conclusions drawn from the data of Sections II and III of this progress report can be summarized as follows:

1. Attainment of the long range peak and average power goals of 10 megawatts peak and 20 kw average is feasible using present and near future techniques to be developed or studied as part of this program.

2. Design to intermediate specifications is not useful in itself. Final specifications will be used as design goals.

3. The polarizer design of Section 2.2.4 with two separate receiver outputs is recommended. Although relatively complex, it offers complete versatility to the system and permits the use of the polarizer as a first stage duplexer.

4. Phaser test sections using low $4\pi M_s$ have been evaluated to the full power capability available with the needs of this program. Further adjustment of phase shift/unit length is required.

5. Driver development is under way and present progress indicates availability as needed for breadboard testing for 90 degree phase shift elements later in this program.

4.2 RECOMMENDATIONS

It is recommended that the polarizer of Section 2.2.4 be chosen for the final design. This recommendation is based upon the overall flexibility of this design coupled with the reduced power handling requirement of any phaser element.

It is also recommended that further testing at high average and peak powers beyond those presently available be carried out to verify the accuracy of predictions and to study the problems encountered with long (40 microsecond) pulse operation.

SECTION V

PROGRAM FOR THE REMAINING HALF

During the remaining half of this program,further studies will be carried out in both the system and component areas with emphasis on component development.

Two developmental models of phaser elements will be fabricated and evaluated as individual elements as well as in their relationship to overall system characteristics.

As a result of this study, Sperry will make a series of recommendations as to type and design of the polarizer to be manufactured later.

SECTION VI

MEETINGS

During the interval covered by this semiannual report, L. J. Lavedan and J. Duffy (representing Sperry) visited Mr. P. Romanelli and other personnel at RADC to discuss component and system aspects of this polarizer program.

Sperry's approach to this polarizer program study was thoroughly discussed and general agreement was reached.

Much of the discussion concerned the system aspects of this program wherein Sperry was able to more fully determine the system needs, and as a result, the study discussed in Section II of this report was carried out.

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Lavedan, L. J., Jr

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
RADC Project Engineer P. A. Romanelli, EMATE AC 315 330-4251.	Rome Air Development Center (EMATE) Techniques Branch Griffiss AFB New York

13. ABSTRACT

The objective of this work is the study and experimental verification leading to the design of a high power S-band variable polarizer. This polarizer is to transform the TE_{10} mode to vertical linear, clockwise circular, counterclockwise circular, and horizontal linear polarizations. Switching time between degrees of polarization is to be 200 microseconds or less. The characteristics of the variable polarizer include the objectives of 1 mw peak, 2 kw average power operating over the band, 3.1 MHz to 3.6 MHz with the study including the feasibility to increase power handling to 10 mw peak, 20 kw average.

Recent results indicate the feasibility of attaining the design goals by the use of nonreciprocal waveguide latching phasers as the active elements of the polarizer. Polarizer power levels to 920 kw peak and 3600 watts average (depending upon polarizer configuration) have been attained, the present limit being the testing facilities available.

Studies have included various polarizer configurations which appear compatible with system concepts and the development in individual phaser elements necessary to meet polarizer requirements.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Polarizer						
Horizontal linear						
Vertical linear						
Left& right circular polarize						
RF polarizer						
Ferrite phase shifter						
High power phase shifter						

Security Classification